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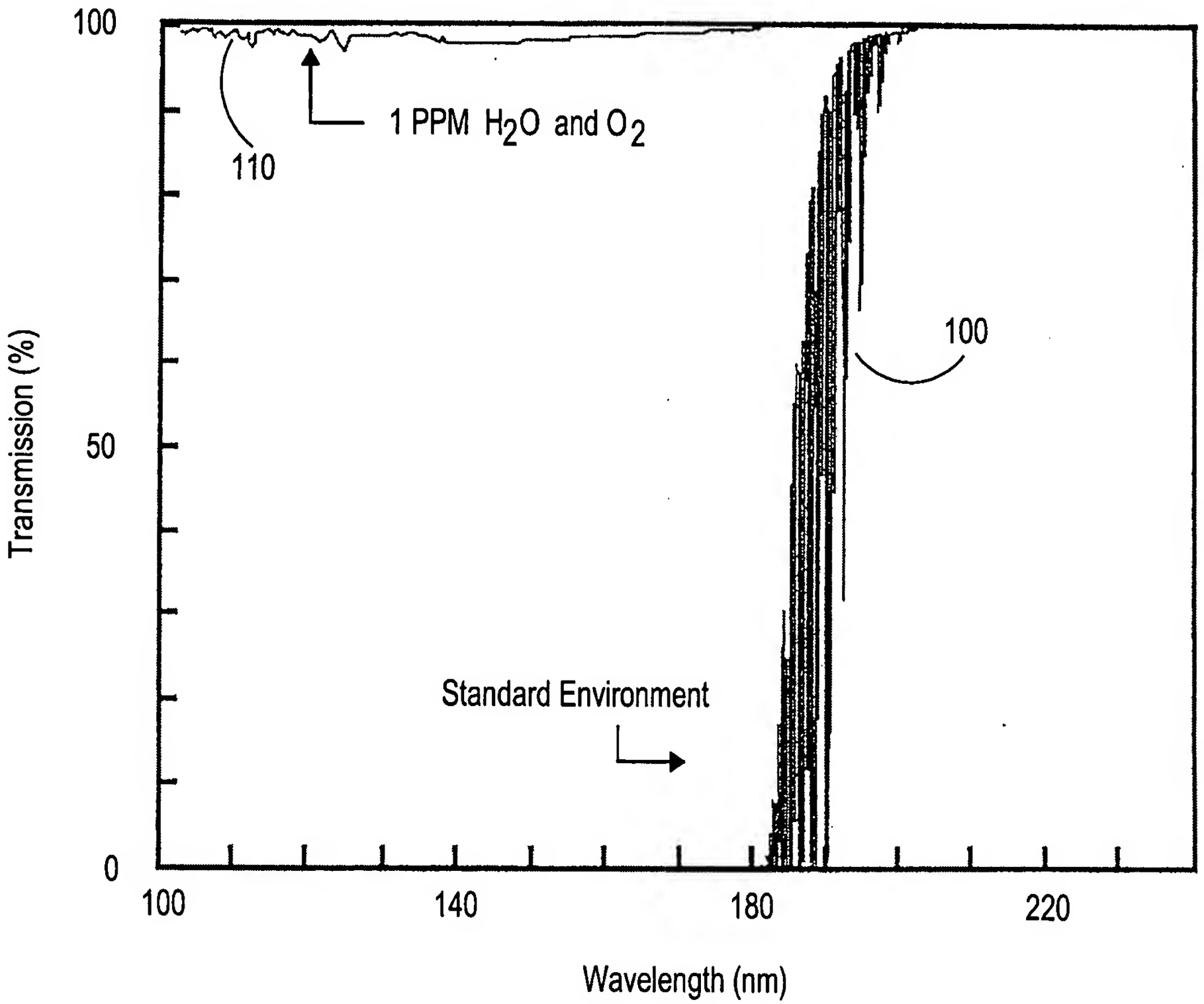


FIG. 1

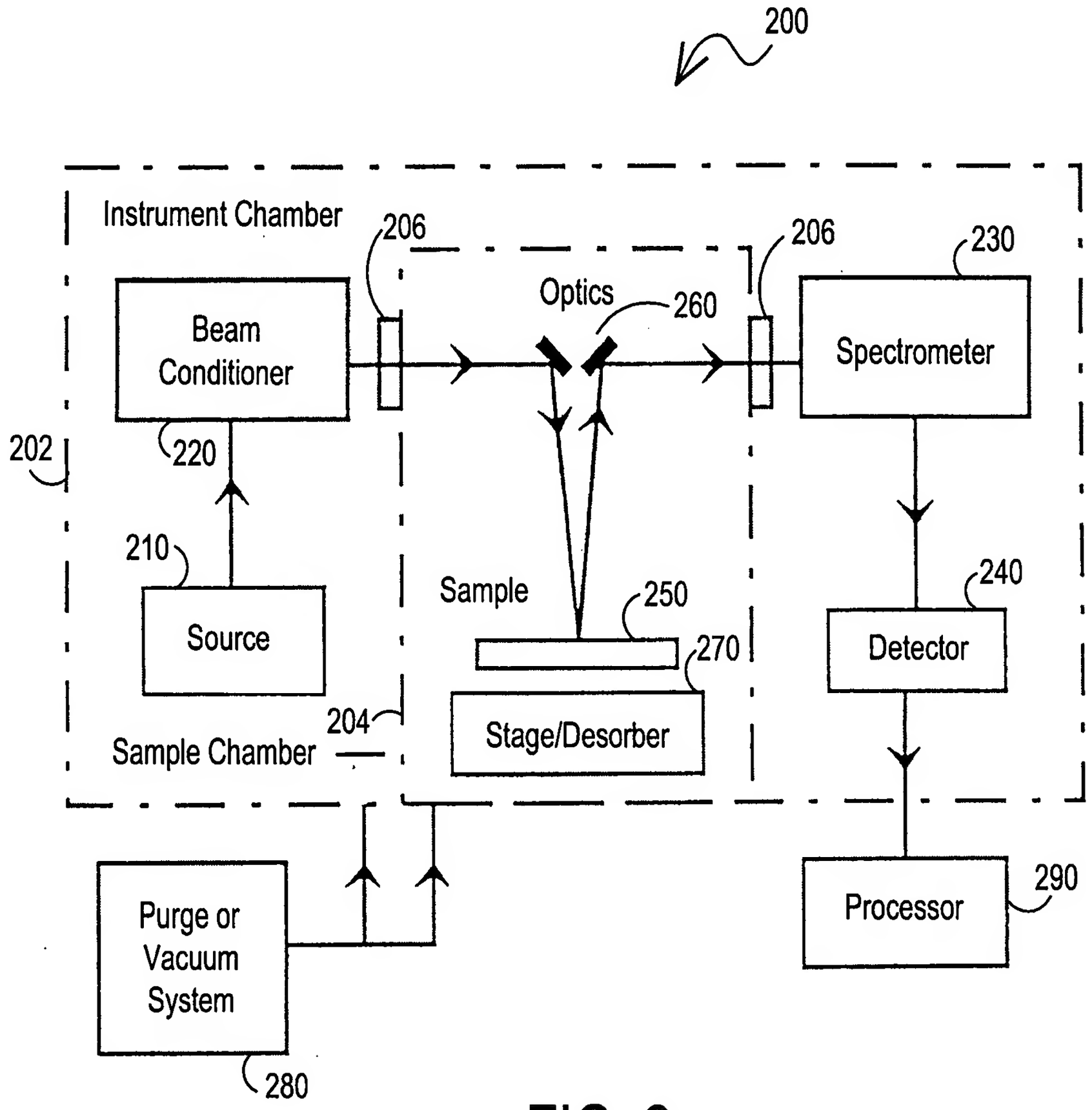
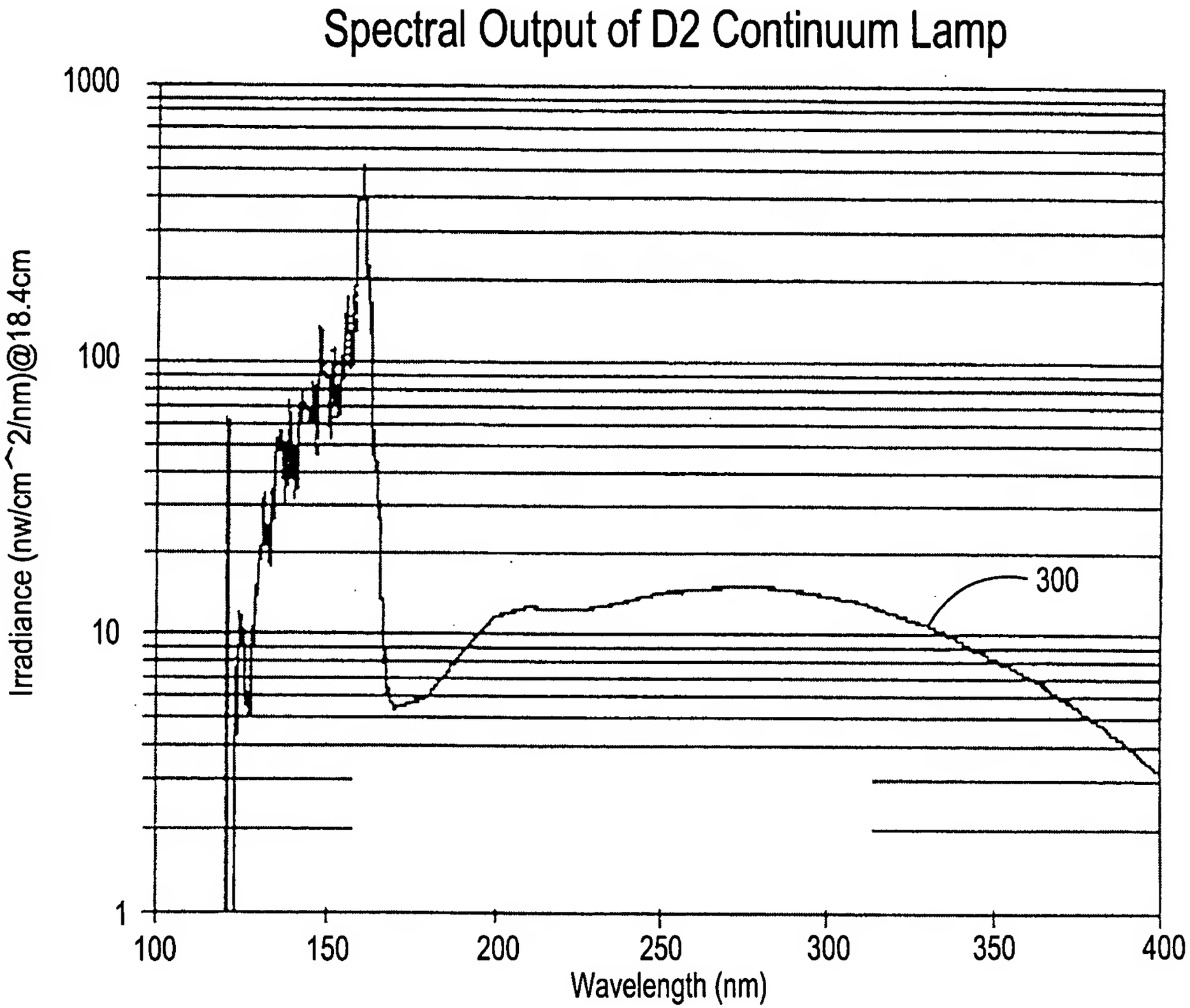

200
Instrument Chamber
206
206
230
Optics
260
Beam
Conditioner
Spectrometer
202
220
210
Source
Sample
250
270
240
Detector
204
Sample Chamber
Stage/Desorber
Purge or
Vacuum
System
280
Processor
290

FIG. 2



NIST Calibration (1nm Bandpass)

FIG. 3

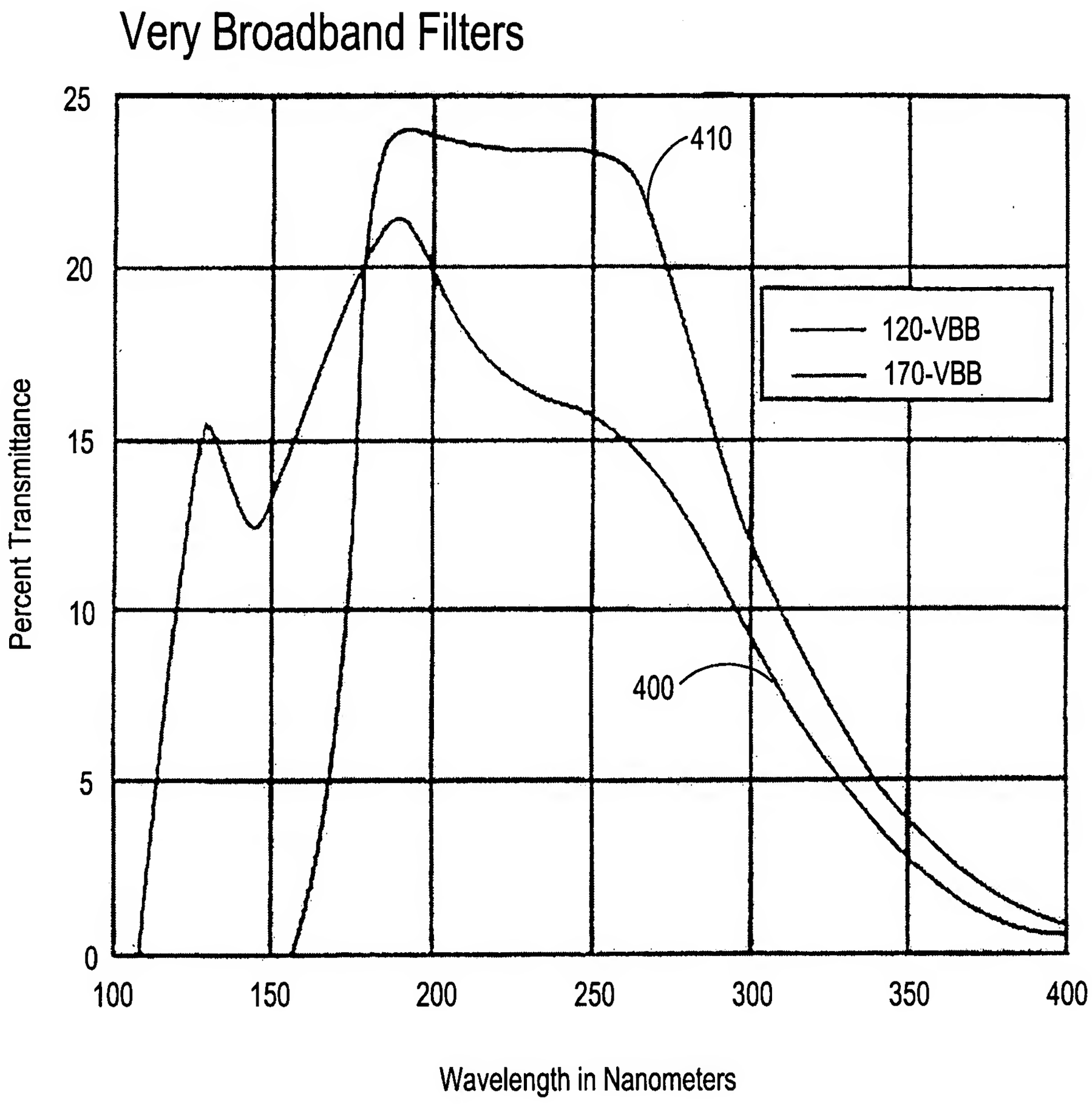

Very Broadband Filters
25
20
15
10
5
0
100
150
200
250
300
350
400
410
400
120-VBB
170-VBB
Percent Transmittance
Wavelength in Nanometers

FIG. 4

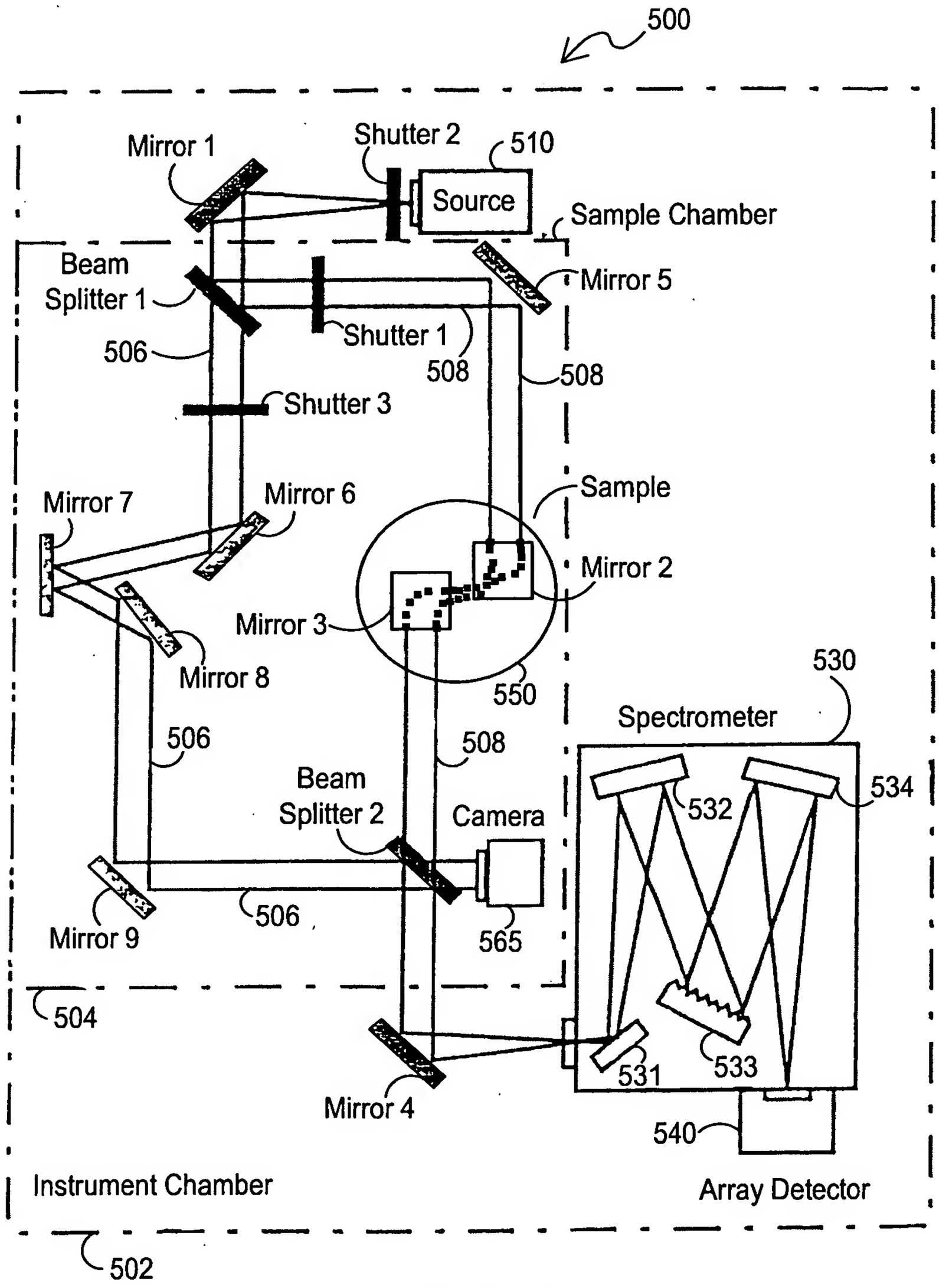

500
Mirror 1
Shutter 2
510
Source
Sample Chamber
Beam
Splitter 1
Mirror 5
Shutter 1
506
508
508
Shutter 3
Mirror 7
Mirror 6
Sample
Mirror 2
Mirror 3
Mirror 8
550
530
Spectrometer
506
508
Beam
Splitter 2
Camera
532
534
506
Mirror 9
565
504
531
533
Mirror 4
540
Instrument Chamber
Array Detector
502

FIG. 5

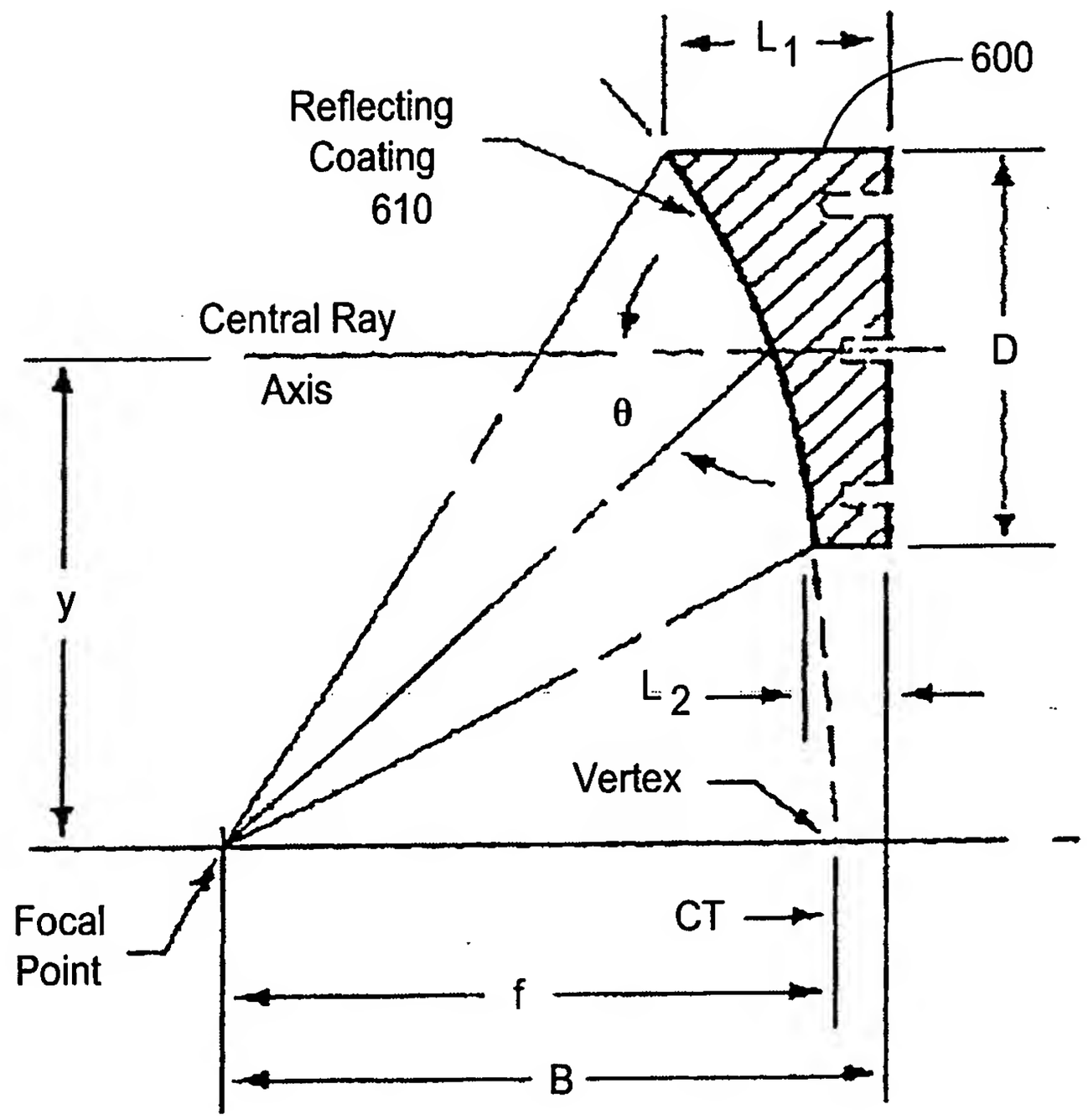

L1
600
Reflecting
Coating
610
Central Ray
Axis
θ
D
y
L2
Vertex
Focal
Point
CT
f
B

FIG. 6

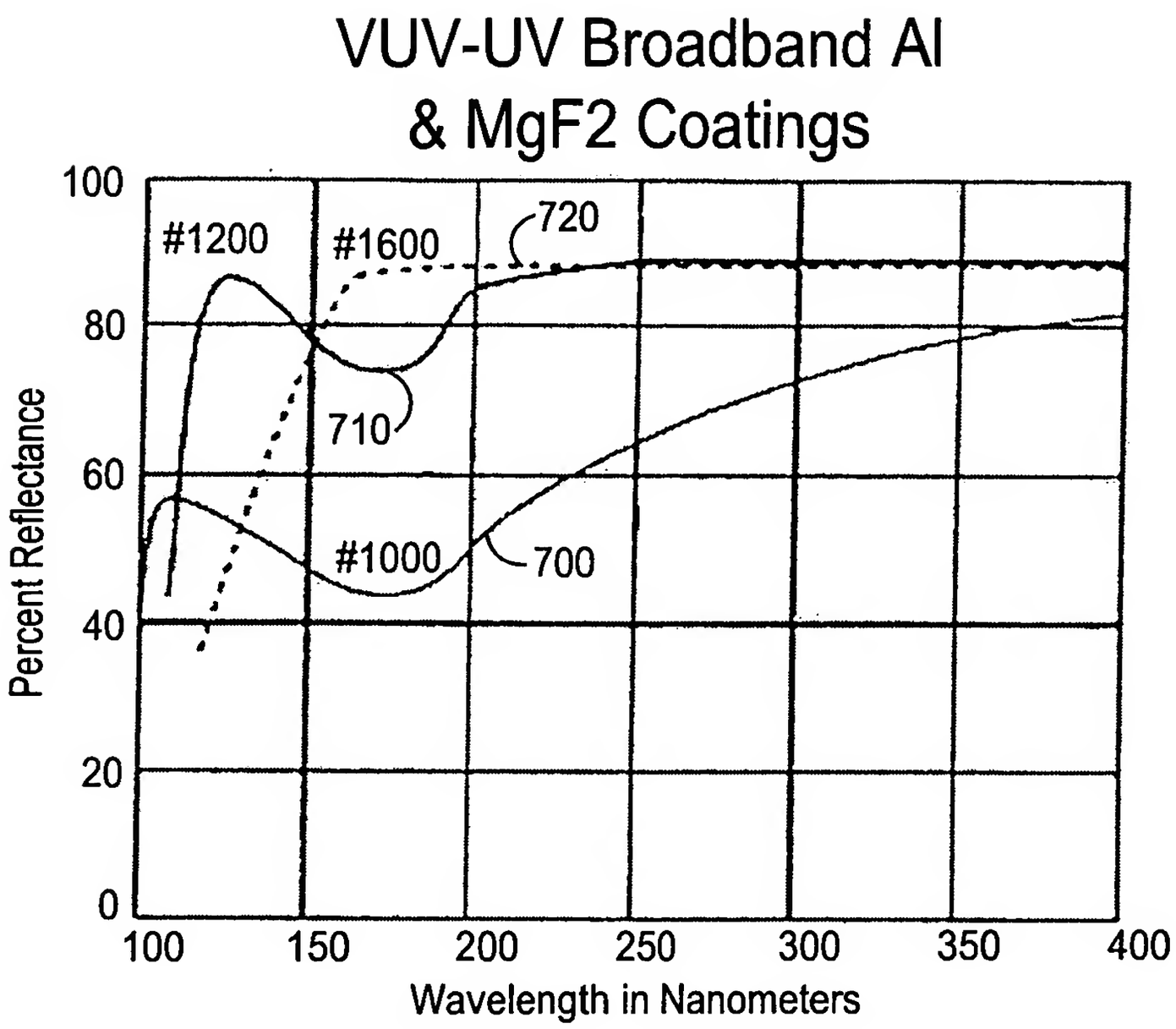

VUV-UV Broadband Al
& MgF2 Coatings
100
80
60
40
20
0
Percent Reflectance
#1200
#1600
720
710
#1000
700
100
150
200
250
300
350
400
Wavelength in Nanometers

FIG. 7

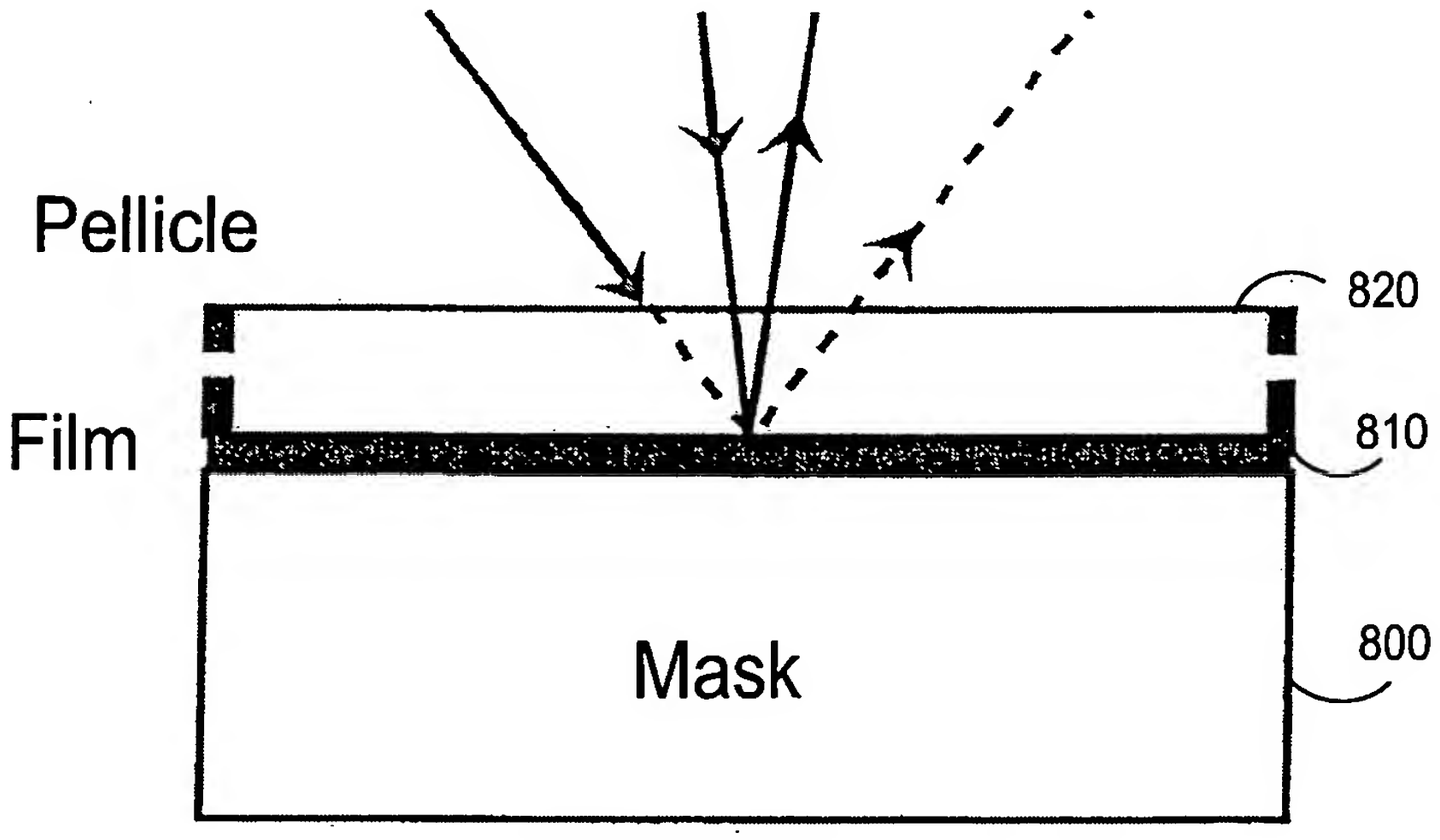

Pellicle
820
Film
810
Mask
800

FIG. 8

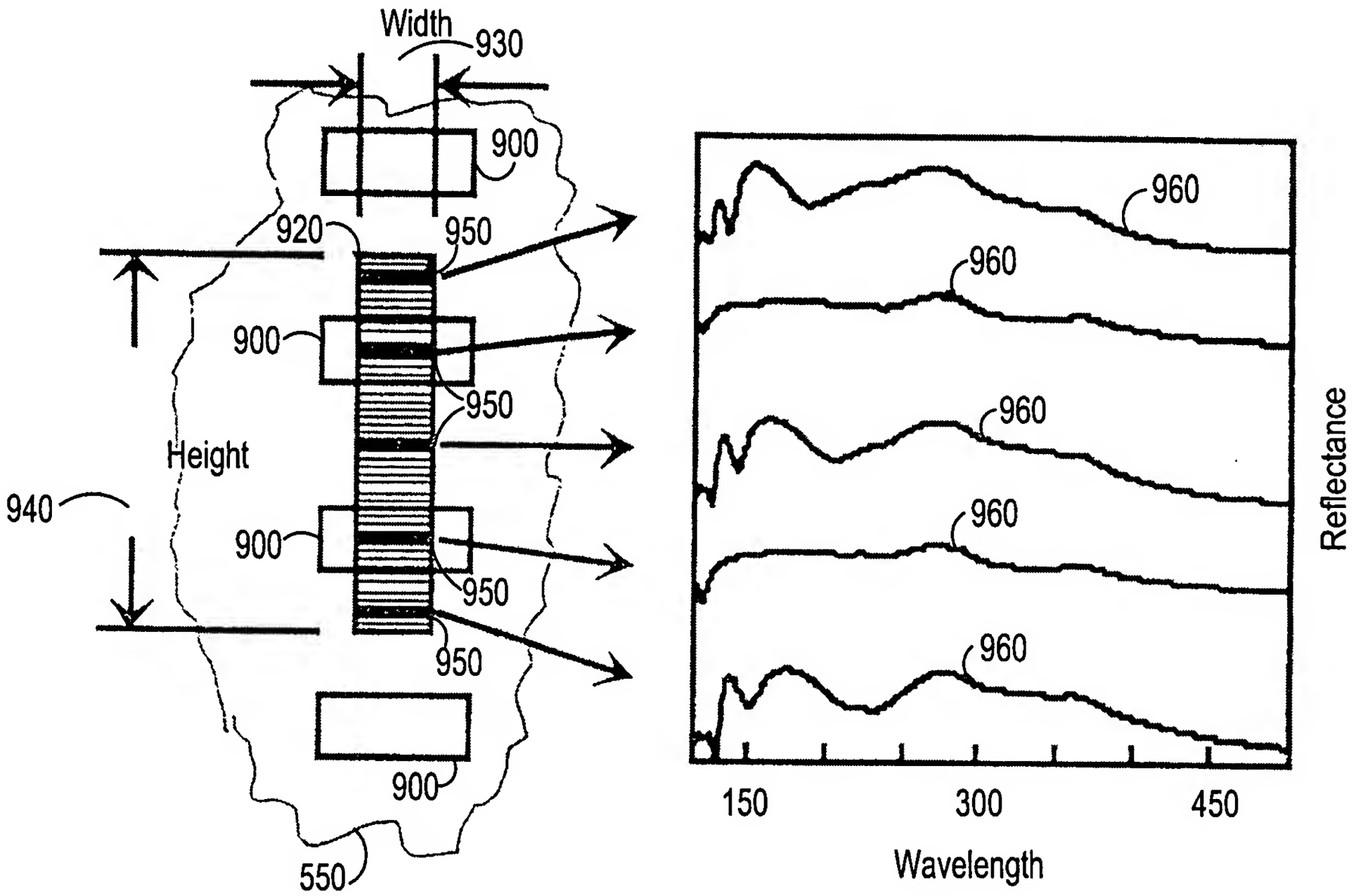

Width
930
900
920
950
900
950
Height
940
900
950
950
900
550
960
960
960
960
960
Reflectance
150
300
450
Wavelength

Fig. 9

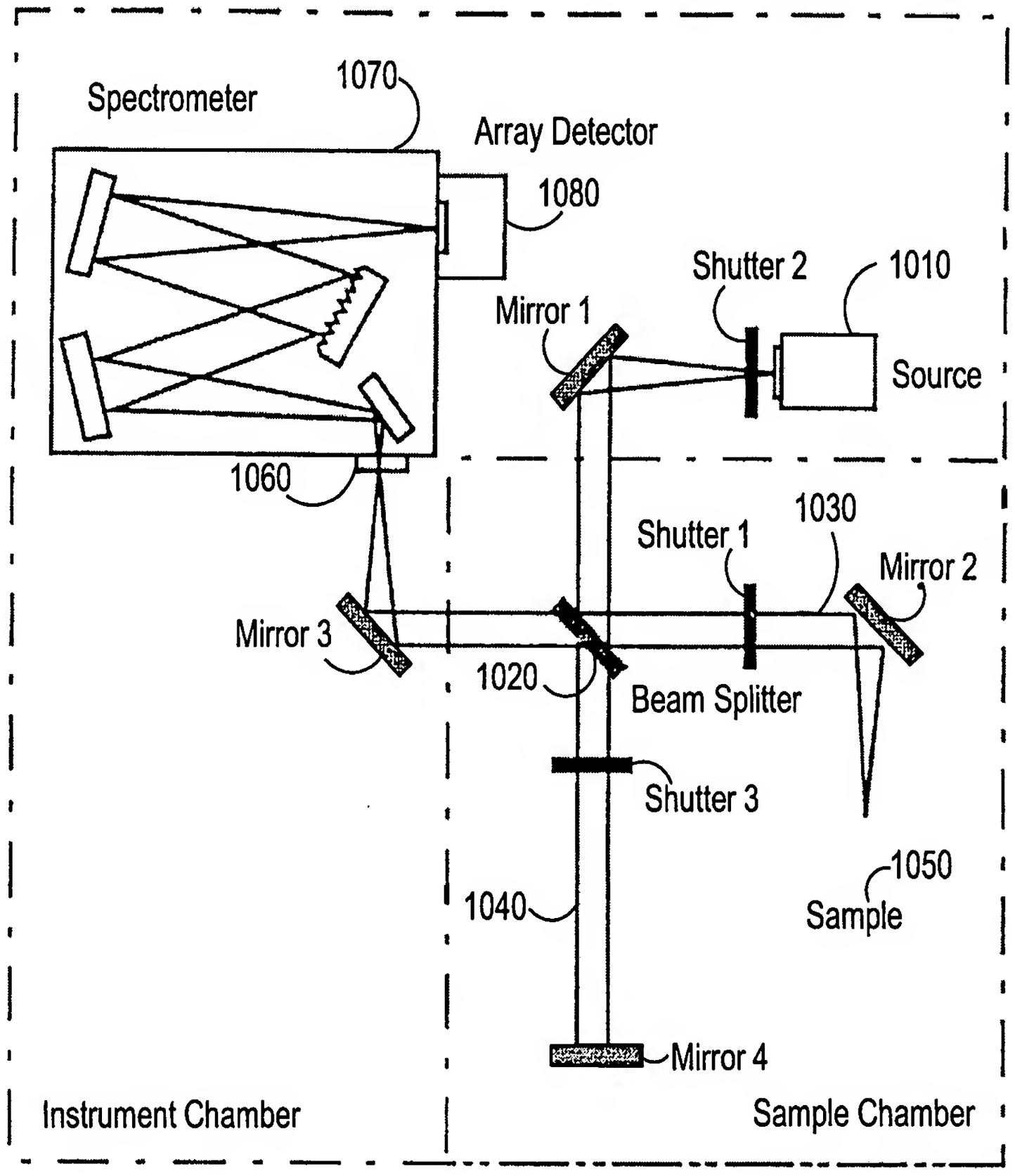

Spectrometer
1070
Array Detector
1080
Shutter 2
1010
Mirror 1
Source
1060
1030
Shutter 1
Mirror 2
Mirror 3
1020
Beam Splitter
Shutter 3
1050
Sample
1040
Mirror 4
Instrument Chamber
Sample Chamber

FIG. 10

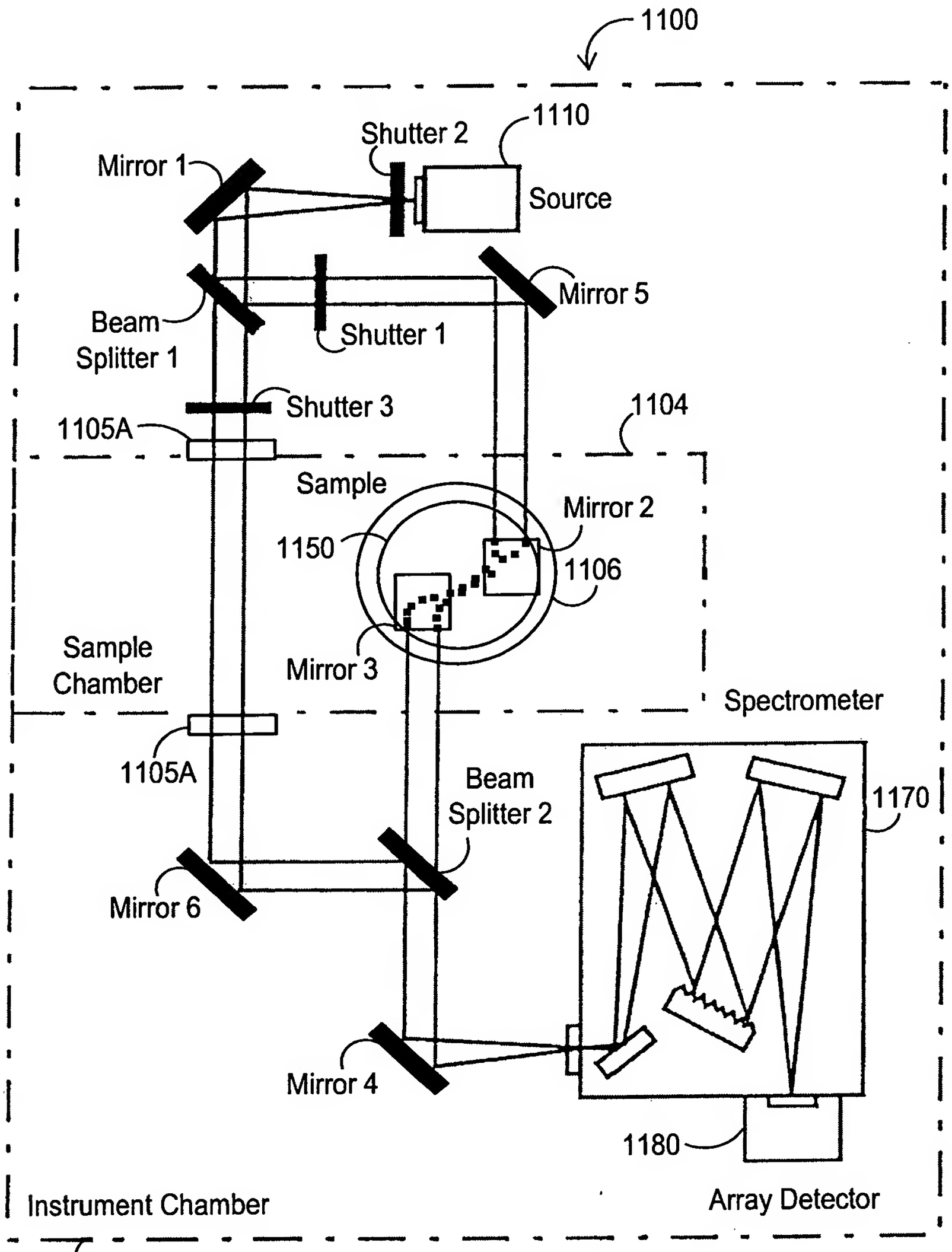

1100
1110
Shutter 2
Mirror 1
Source
Mirror 5
Beam
Splitter 1
Shutter 1
Shutter 3
1105A
1104
Sample
Mirror 2
1150
1106
Mirror 3
Sample
Chamber
Spectrometer
1105A
Beam
Splitter 2
1170
Mirror 6
Mirror 4
1180
Instrument Chamber
Array Detector
1102

FIG. 11

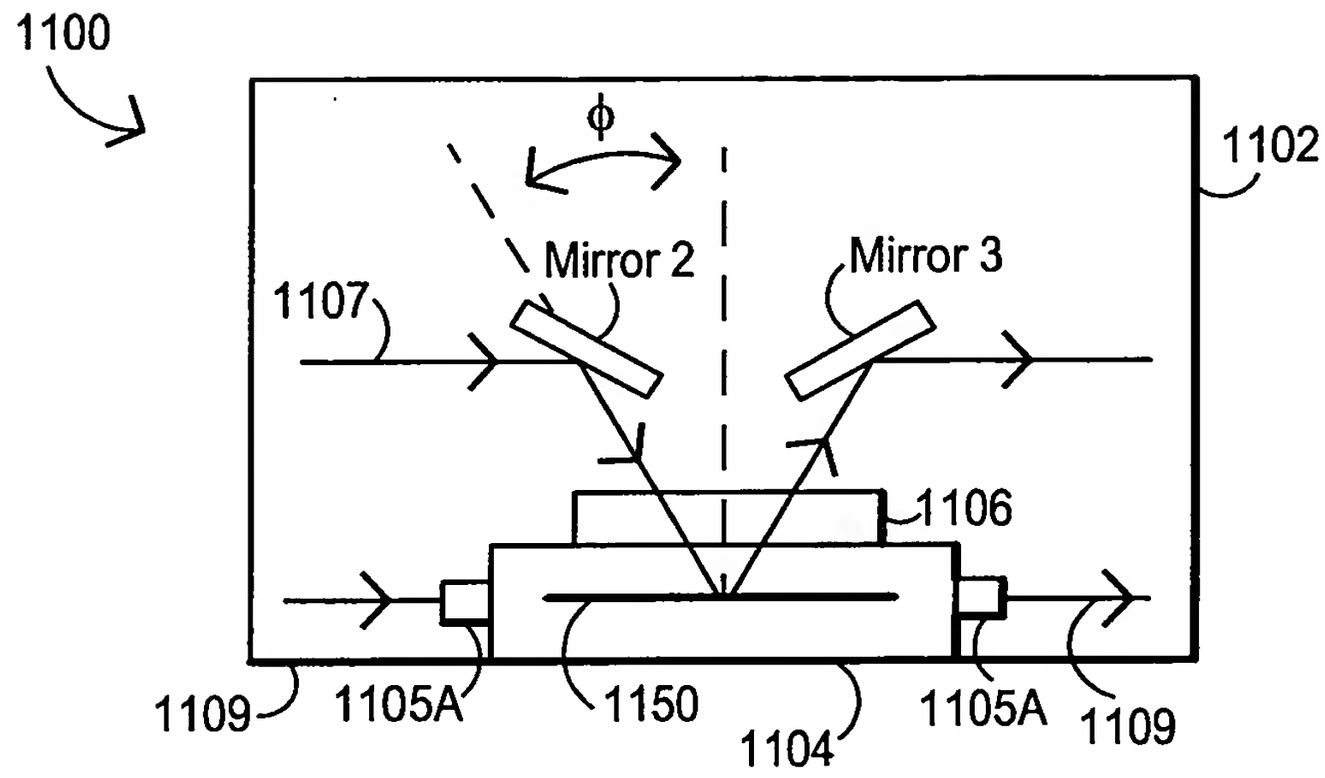


FIG. 11A

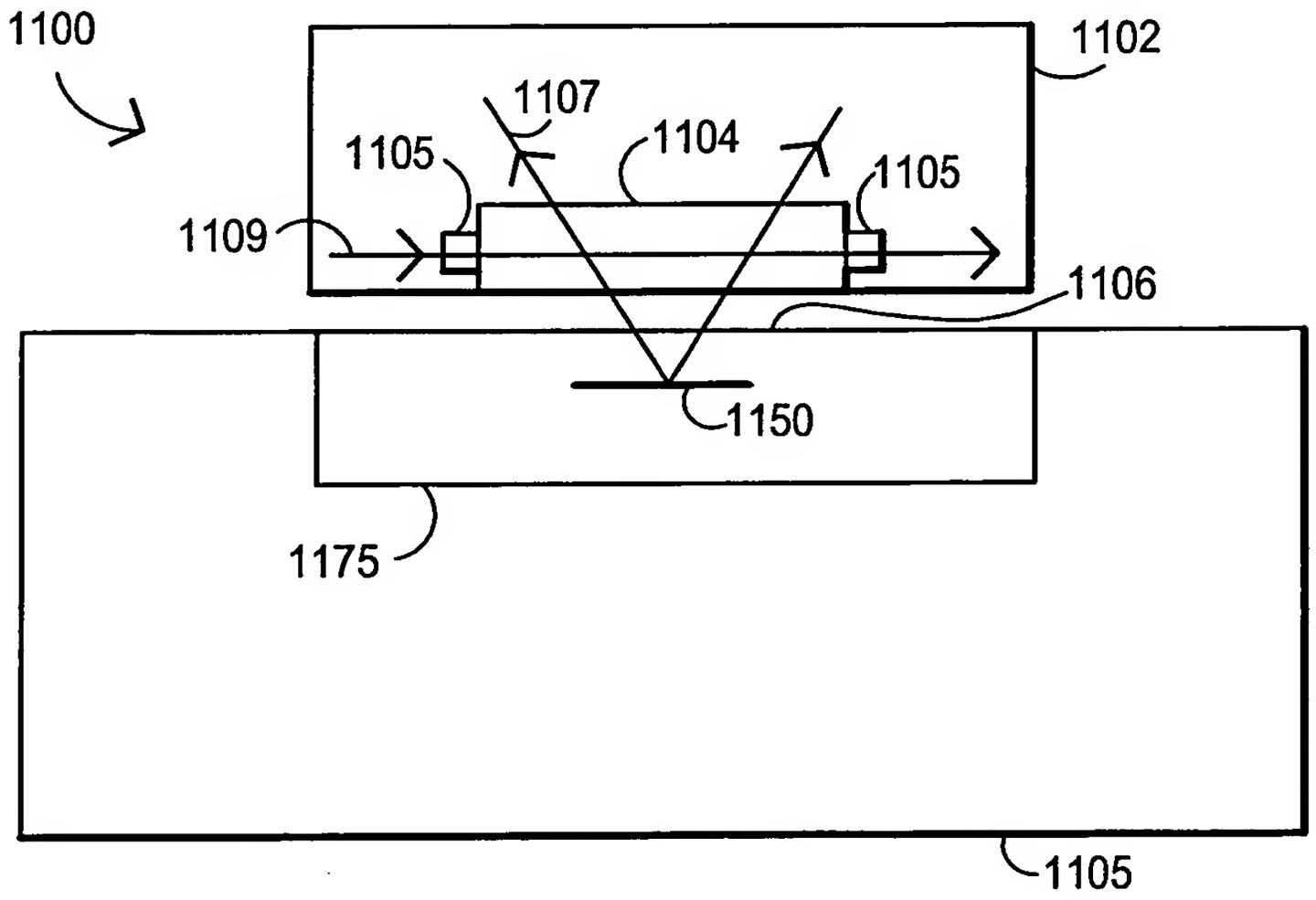


FIG. 11B

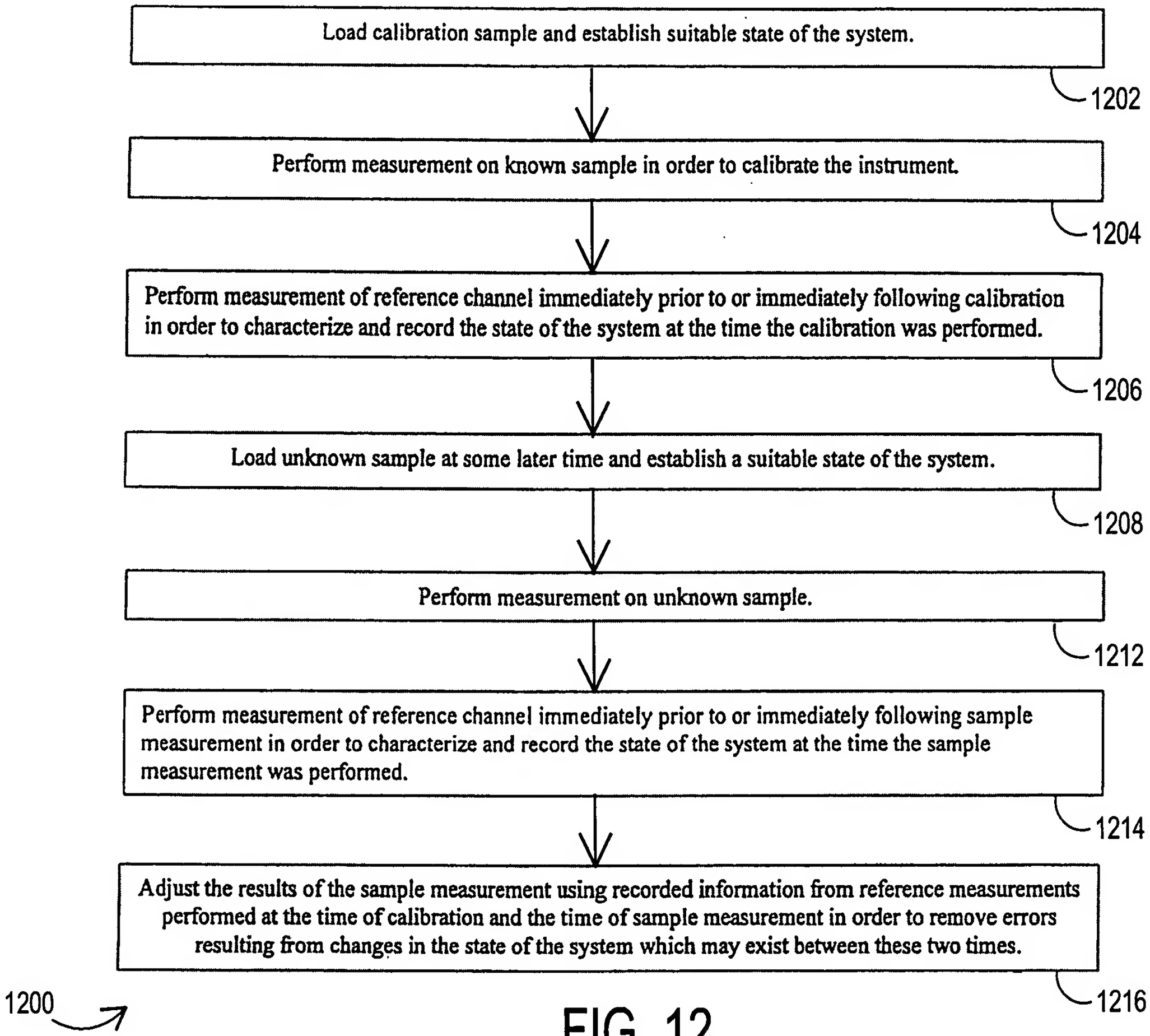

Load calibration sample and establish suitable state of the system.
1202
Perform measurement on known sample in order to calibrate the instrument.
1204
Perform measurement of reference channel immediately prior to or immediately following calibration in order to characterize and record the state of the system at the time the calibration was performed.
1206
Load unknown sample at some later time and establish a suitable state of the system.
1208
Perform measurement on unknown sample.
1212
Perform measurement of reference channel immediately prior to or immediately following sample measurement in order to characterize and record the state of the system at the time the sample measurement was performed.
1214
Adjust the results of the sample measurement using recorded information from reference measurements performed at the time of calibration and the time of sample measurement in order to remove errors resulting from changes in the state of the system which may exist between these two times.
1216
1200

FIG. 12

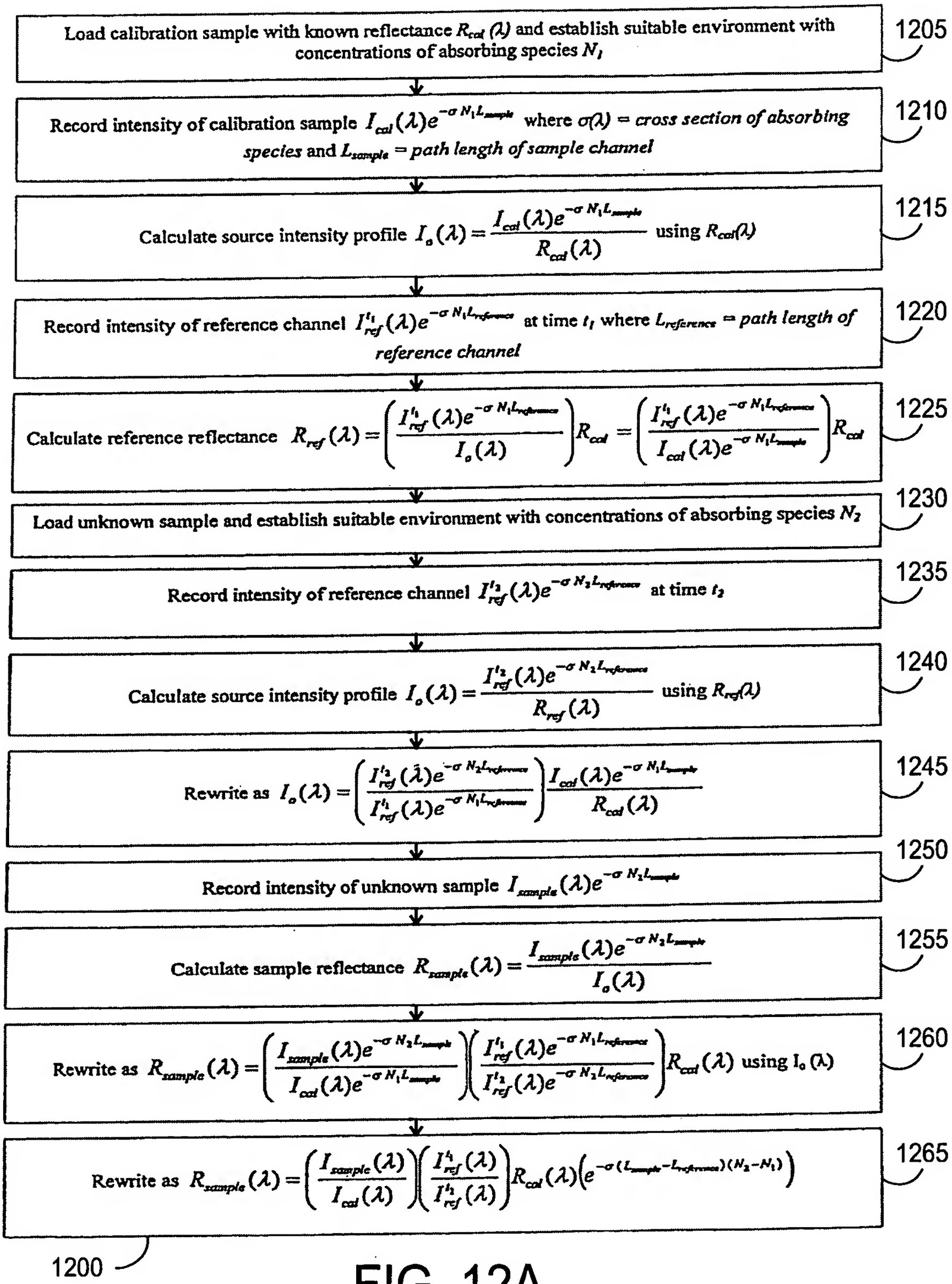

Load calibration sample with known reflectance $R_{cal}(\lambda)$ and establish suitable environment with concentrations of absorbing species N_1
1205
Record intensity of calibration sample $I_{cal}(\lambda)e^{-\sigma N_1 L_{sample}}$ where $\sigma(\lambda)$ = cross section of absorbing species and L_{sample} = path length of sample channel
1210
Calculate source intensity profile $I_o(\lambda) = \frac{I_{cal}(\lambda)e^{-\sigma N_1 L_{sample}}}{R_{cal}(\lambda)}$ using $R_{cal}(\lambda)$
1215
Record intensity of reference channel $I_{ref}^{t_1}(\lambda)e^{-\sigma N_1 L_{reference}}$ at time t_1 where $L_{reference}$ = path length of reference channel
1220
Calculate reference reflectance $R_{ref}(\lambda) = \left(\frac{I_{ref}^{t_1}(\lambda)e^{-\sigma N_1 L_{reference}}}{I_o(\lambda)}\right)R_{cal} = \left(\frac{I_{ref}^{t_1}(\lambda)e^{-\sigma N_1 L_{reference}}}{I_{cal}(\lambda)e^{-\sigma N_1 L_{sample}}}\right)R_{cal}$
1225
Load unknown sample and establish suitable environment with concentrations of absorbing species N_2
1230
Record intensity of reference channel $I_{ref}^{t_2}(\lambda)e^{-\sigma N_2 L_{reference}}$ at time t_2
1235
Calculate source intensity profile $I_o(\lambda) = \frac{I_{ref}^{t_2}(\lambda)e^{-\sigma N_2 L_{reference}}}{R_{ref}(\lambda)}$ using $R_{ref}(\lambda)$
1240
Rewrite as $I_o(\lambda) = \left(\frac{I_{ref}^{t_2}(\lambda)e^{-\sigma N_2 L_{reference}}}{I_{ref}^{t_1}(\lambda)e^{-\sigma N_1 L_{reference}}}\right)\frac{I_{cal}(\lambda)e^{-\sigma N_1 L_{sample}}}{R_{cal}(\lambda)}$
1245
Record intensity of unknown sample $I_{sample}(\lambda)e^{-\sigma N_2 L_{sample}}$
1250
Calculate sample reflectance $R_{sample}(\lambda) = \frac{I_{sample}(\lambda)e^{-\sigma N_2 L_{sample}}}{I_o(\lambda)}$
1255
Rewrite as $R_{sample}(\lambda) = \left(\frac{I_{sample}(\lambda)e^{-\sigma N_2 L_{sample}}}{I_{cal}(\lambda)e^{-\sigma N_1 L_{sample}}}\right)\left(\frac{I_{ref}^{t_1}(\lambda)e^{-\sigma N_1 L_{reference}}}{I_{ref}^{t_2}(\lambda)e^{-\sigma N_2 L_{reference}}}\right)R_{cal}(\lambda)$ using $I_o(\lambda)$
1260
Rewrite as $R_{sample}(\lambda) = \left(\frac{I_{sample}(\lambda)}{I_{cal}(\lambda)}\right)\left(\frac{I_{ref}^{t_1}(\lambda)}{I_{ref}^{t_2}(\lambda)}\right)R_{cal}(\lambda)\left(e^{-\sigma(L_{sample}-L_{reference})(N_2-N_1)}\right)$
1265
1200

FIG. 12A

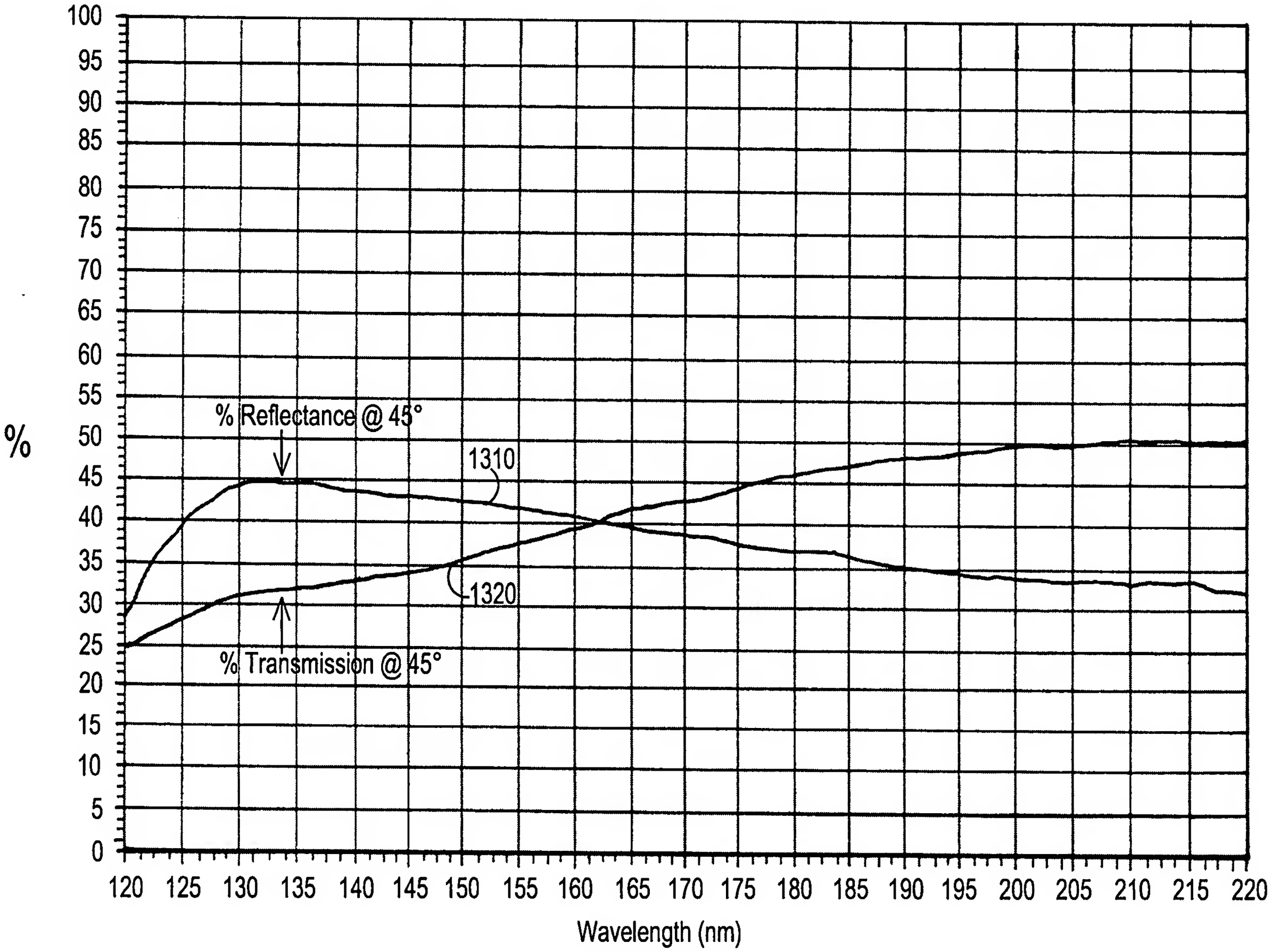

%
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
% Reflectance @ 45°
1310
1320
% Transmission @ 45°
120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220
Wavelength (nm)

FIG. 13

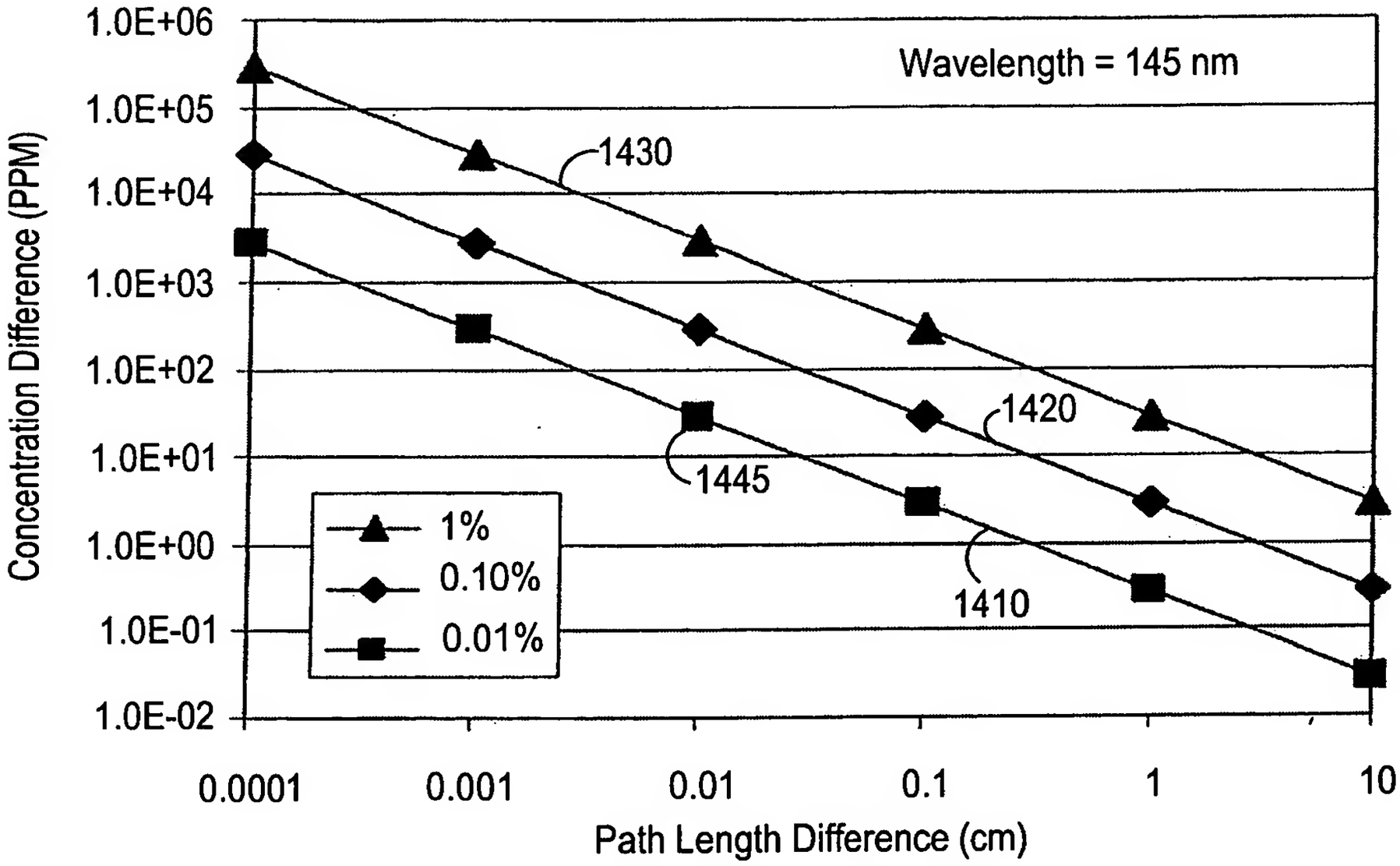

Wavelength = 145 nm
1430
1420
1445
1410
1%
0.10%
0.01%
Concentration Difference (PPM)
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
0.0001
0.001
0.01
0.1
1
10
Path Length Difference (cm)

FIG. 14

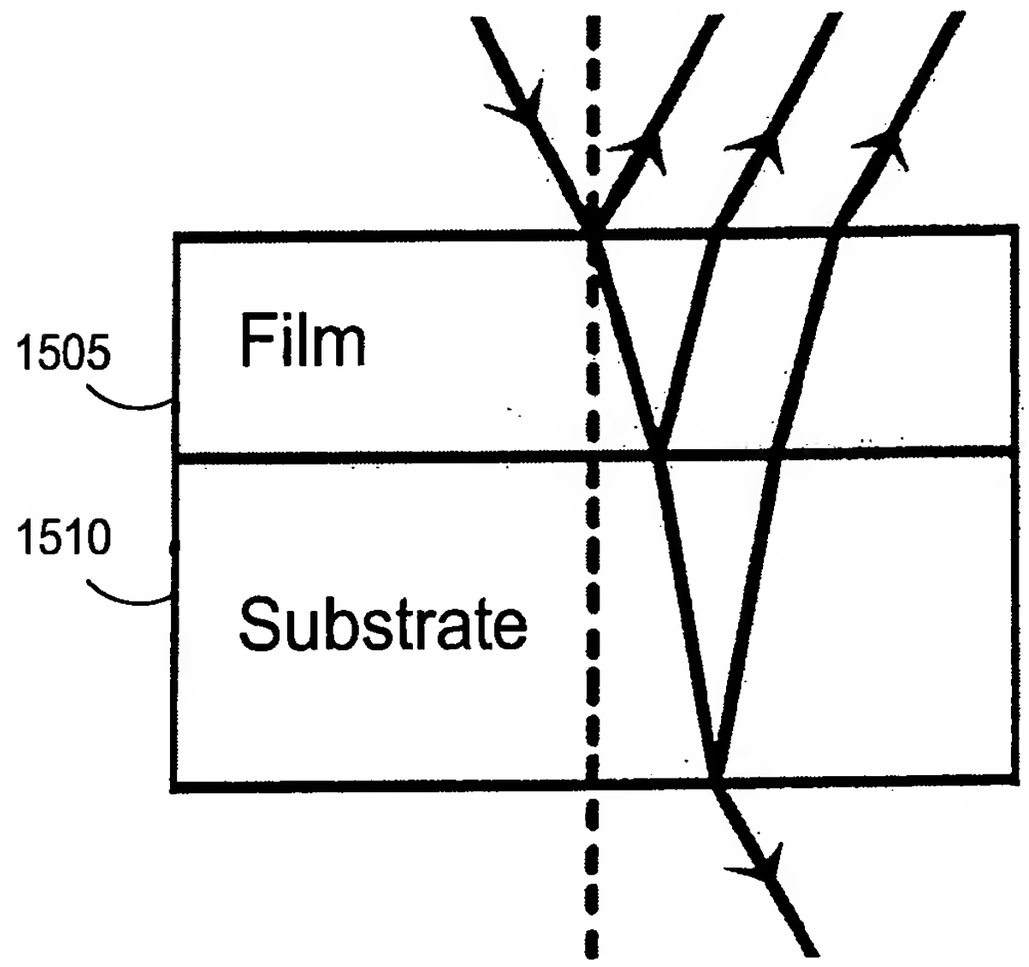

1505
Film
1510
Substrate

FIG. 15

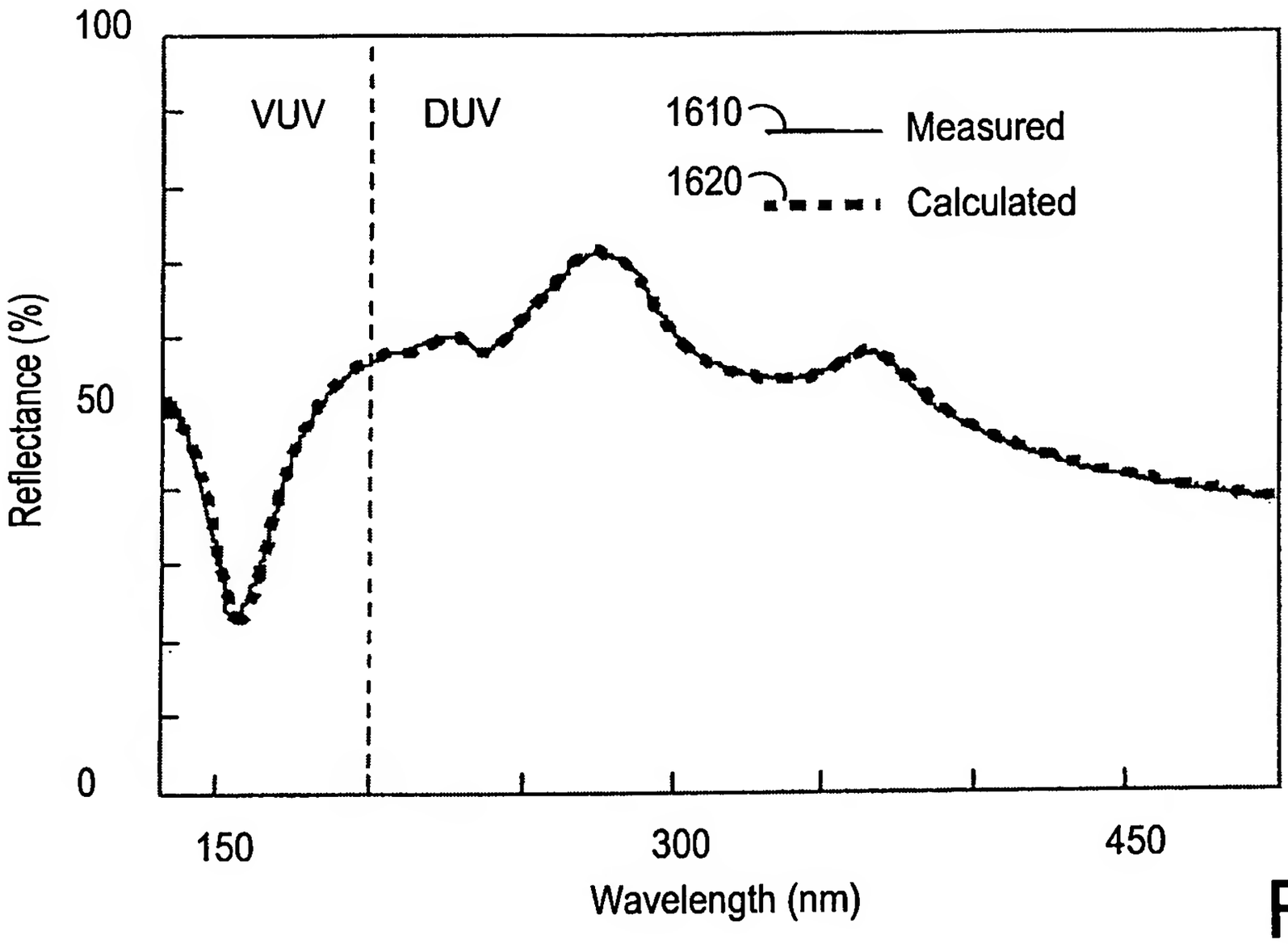

100
50
0
Reflectance (%)
VUV
DUV
1610
Measured
1620
Calculated
150
300
450
Wavelength (nm)

FIG. 16

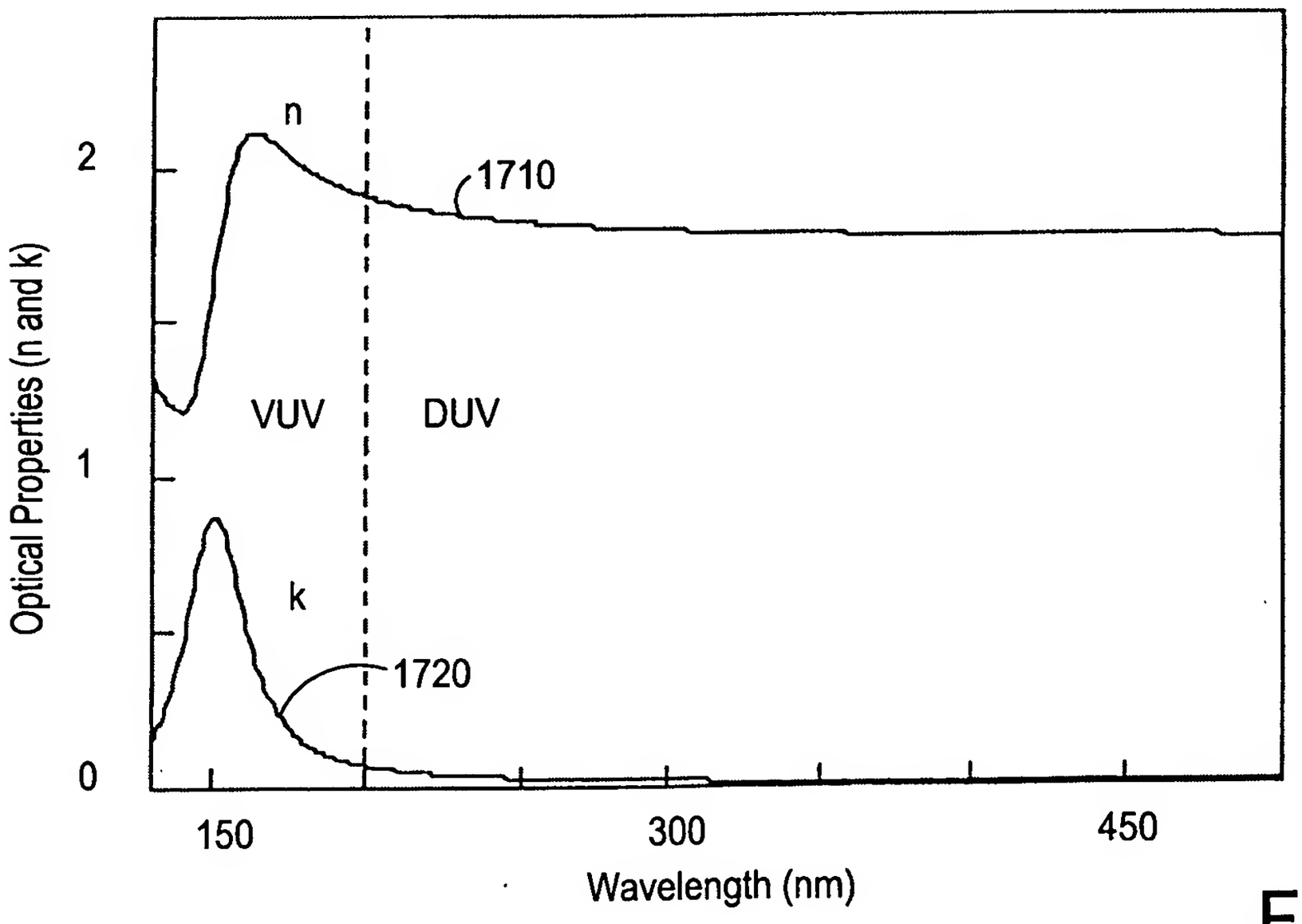

2
1
0
Optical Properties (n and k)
n
1710
VUV
DUV
k
1720
150
300
450
Wavelength (nm)

FIG. 17

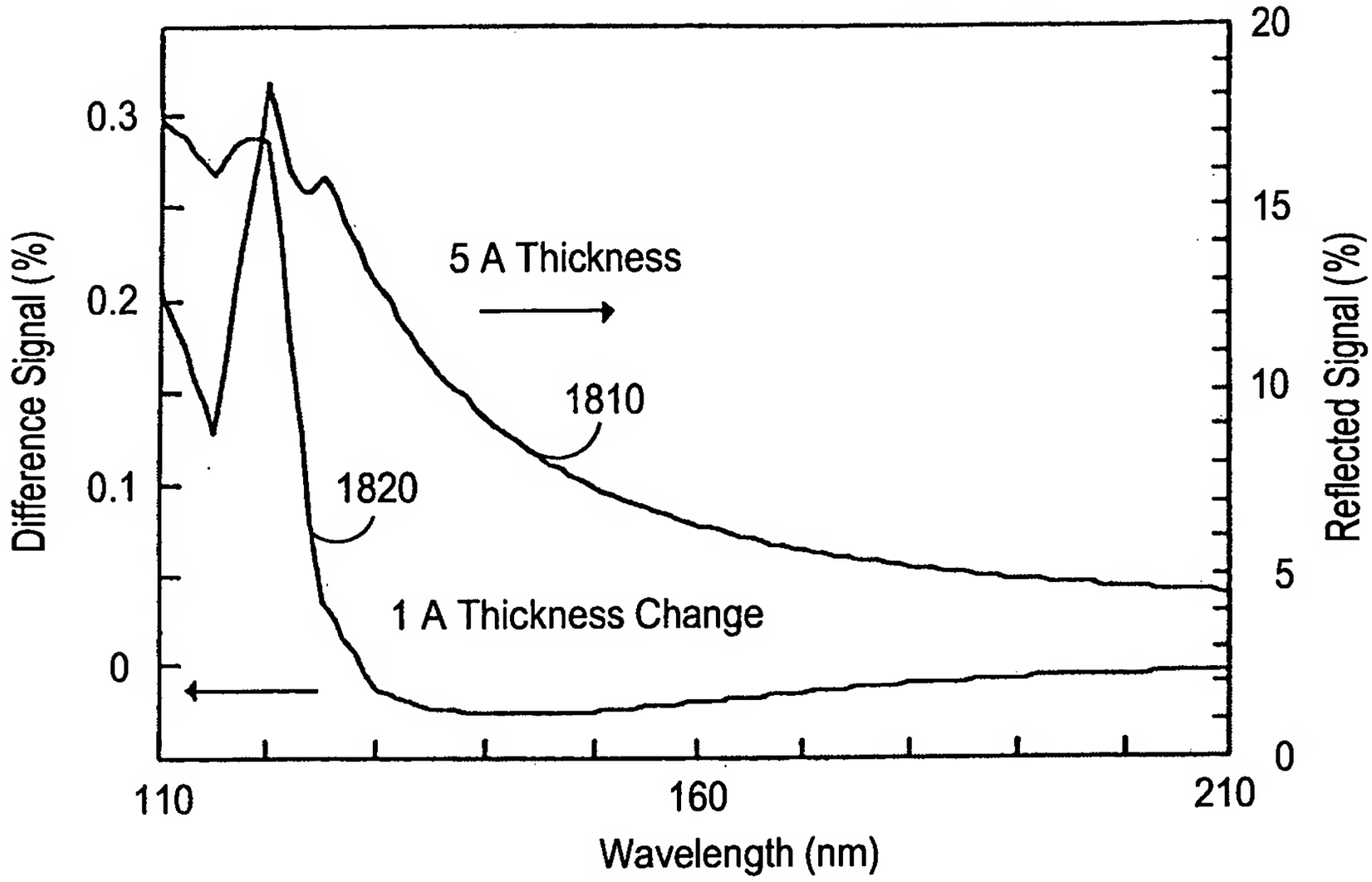

Difference Signal (%)
0.3
0.2
0.1
0
5 A Thickness
1810
1820
1 A Thickness Change
20
15
10
5
0
Reflected Signal (%)
110
160
210
Wavelength (nm)

FIG. 18

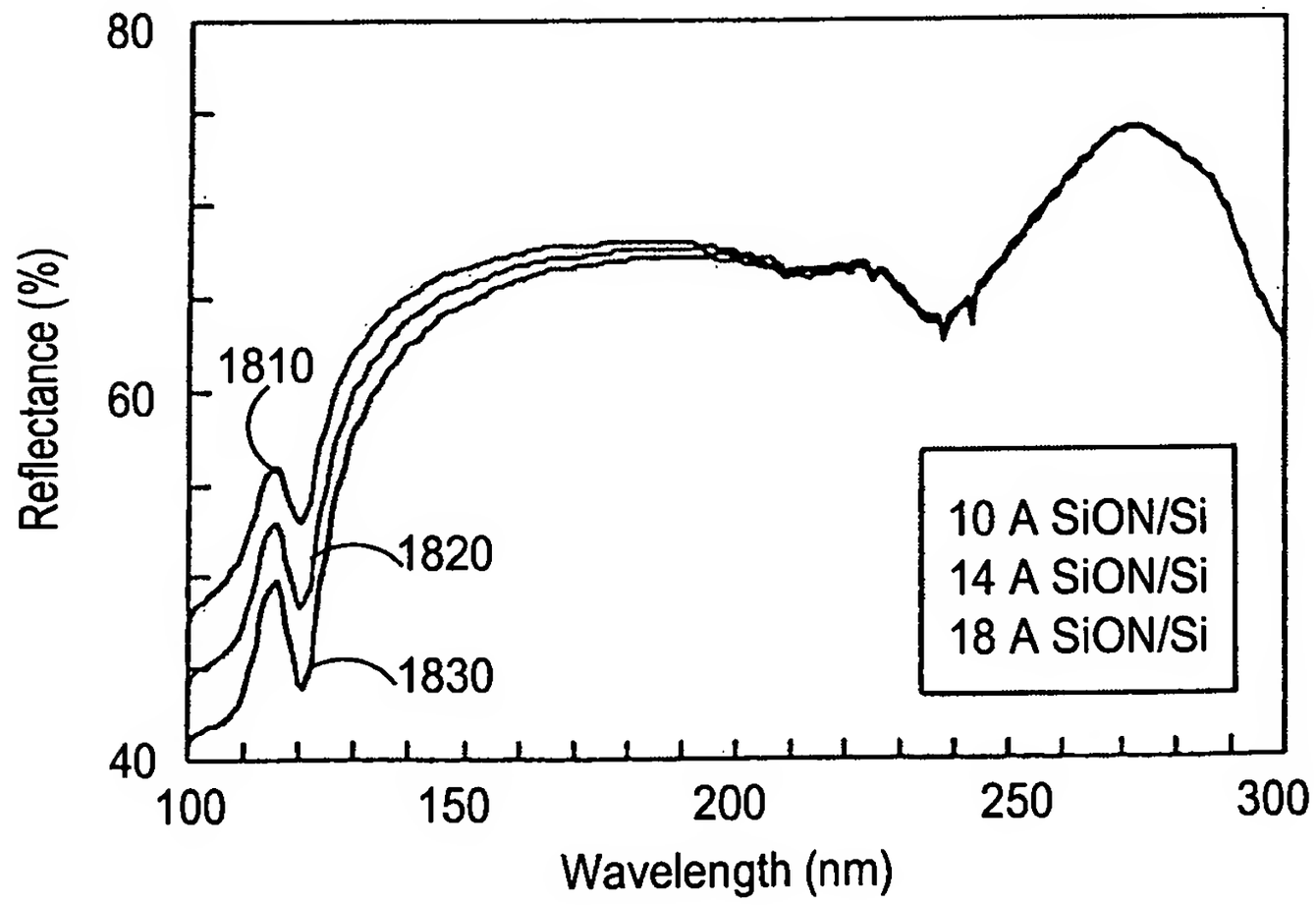

Reflectance (%)
80
60
40
1810
1820
1830
10 A SiON/Si
14 A SiON/Si
18 A SiON/Si
100
150
200
250
300
Wavelength (nm)

FIG. 19

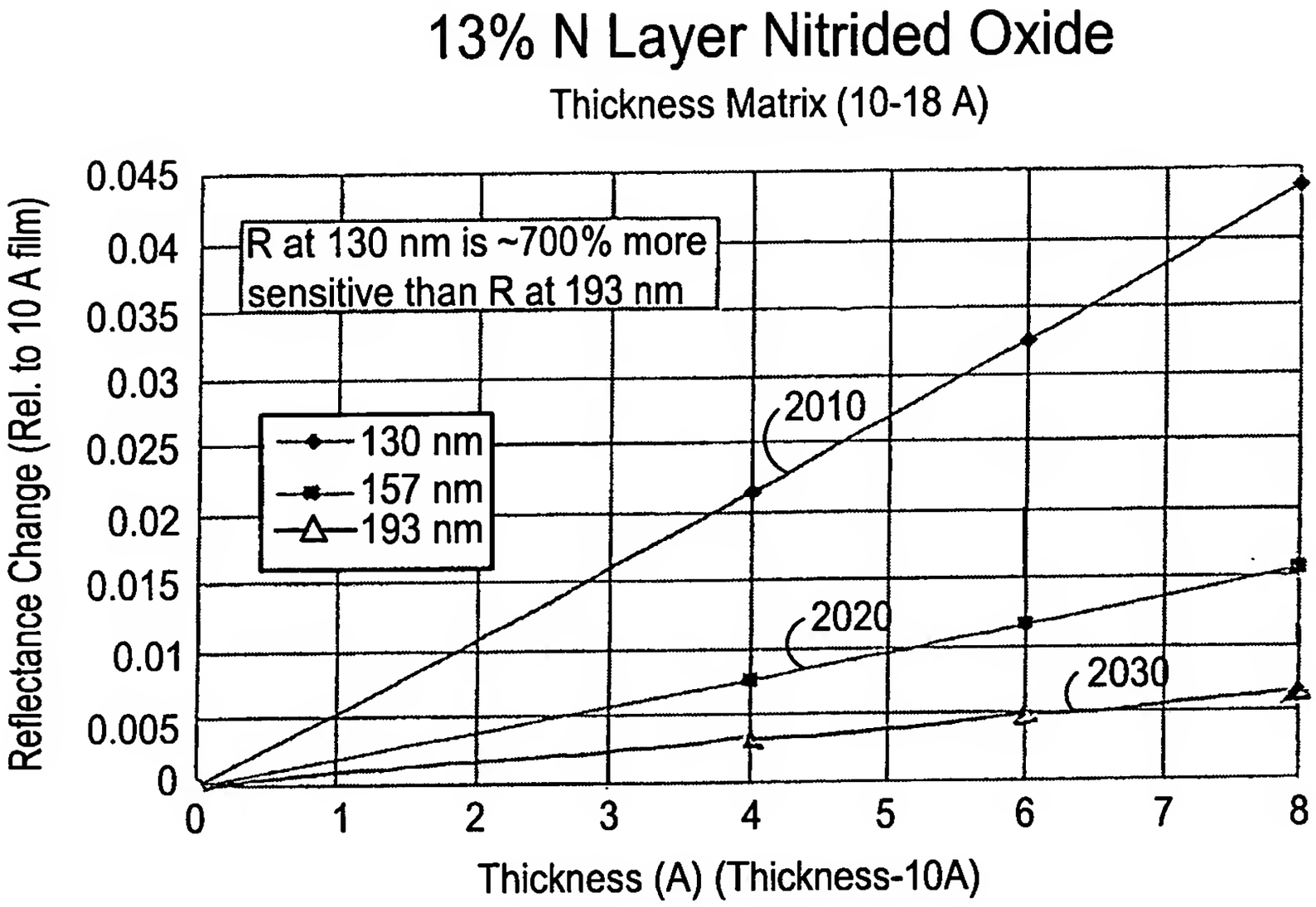

13% N Layer Nitrided Oxide
Thickness Matrix (10-18 A)
R at 130 nm is ~700% more sensitive than R at 193 nm
130 nm
157 nm
193 nm
2010
2020
2030
Reflectance Change (Rel. to 10 A film)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
1
2
3
4
5
6
7
8
Thickness (A) (Thickness-10A)

FIG. 20

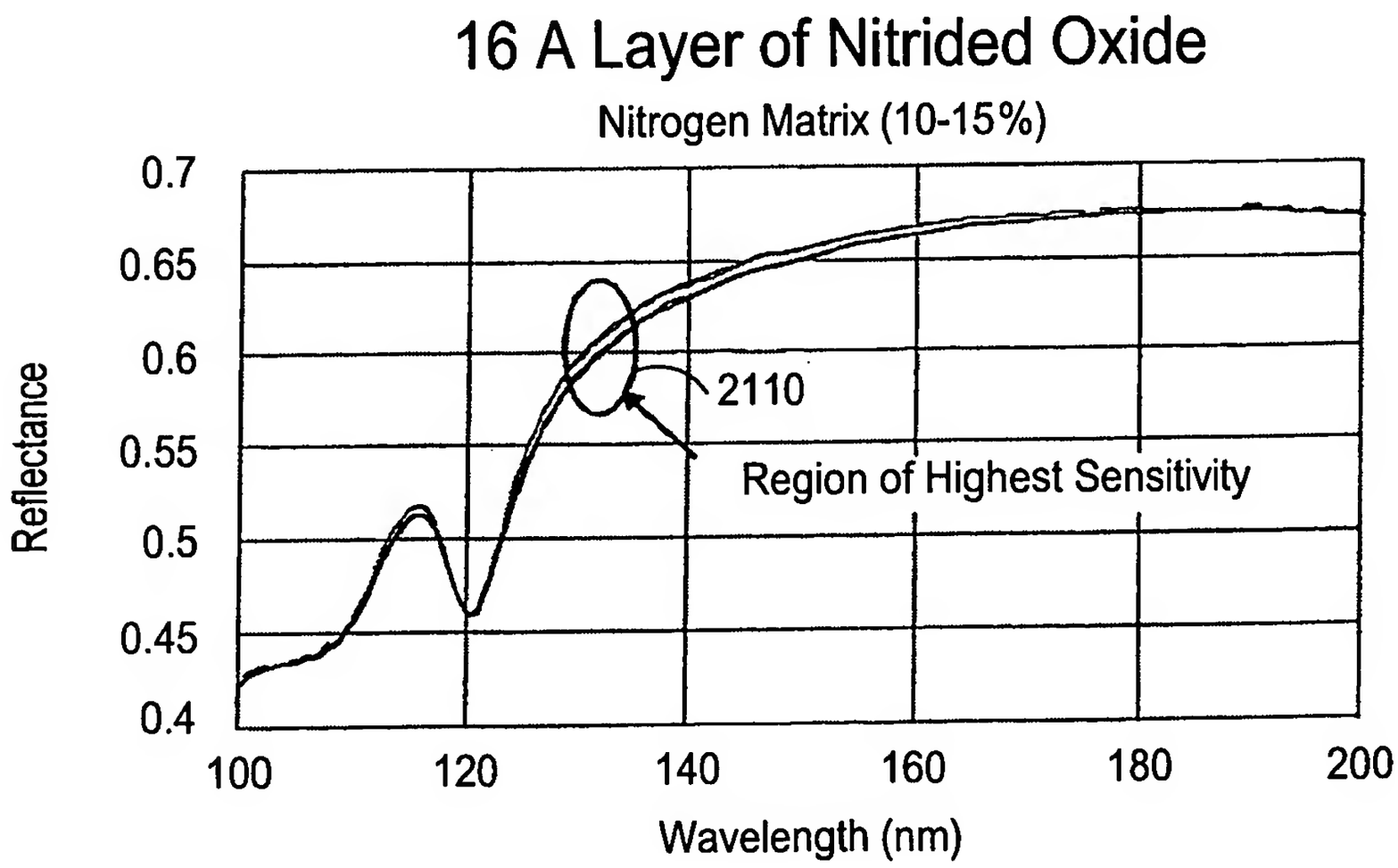

16 A Layer of Nitrided Oxide
Nitrogen Matrix (10-15%)
2110
Region of Highest Sensitivity
Reflectance
0.7
0.65
0.6
0.55
0.5
0.45
0.4
100
120
140
160
180
200
Wavelength (nm)

FIG. 21

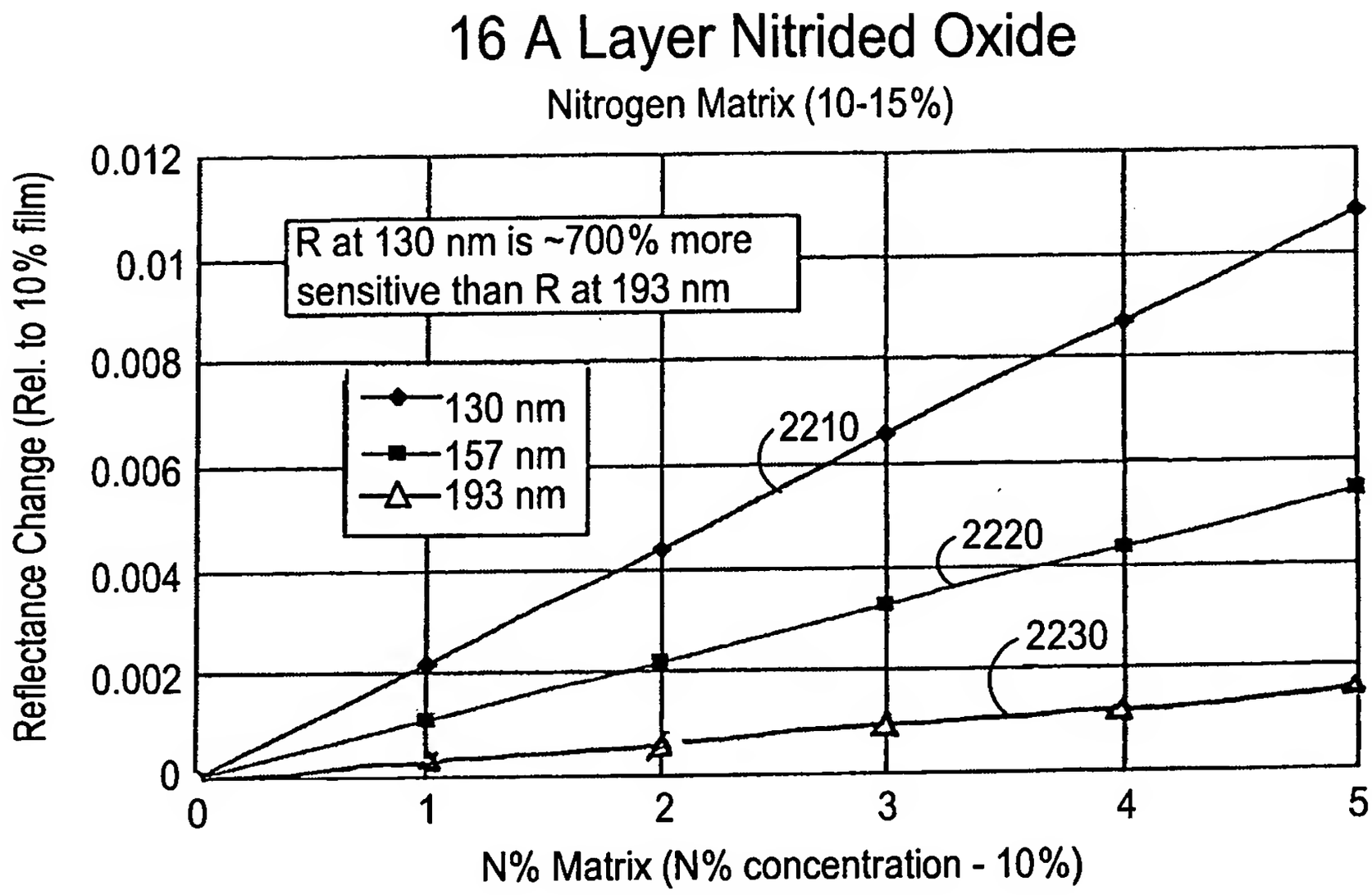


FIG. 22

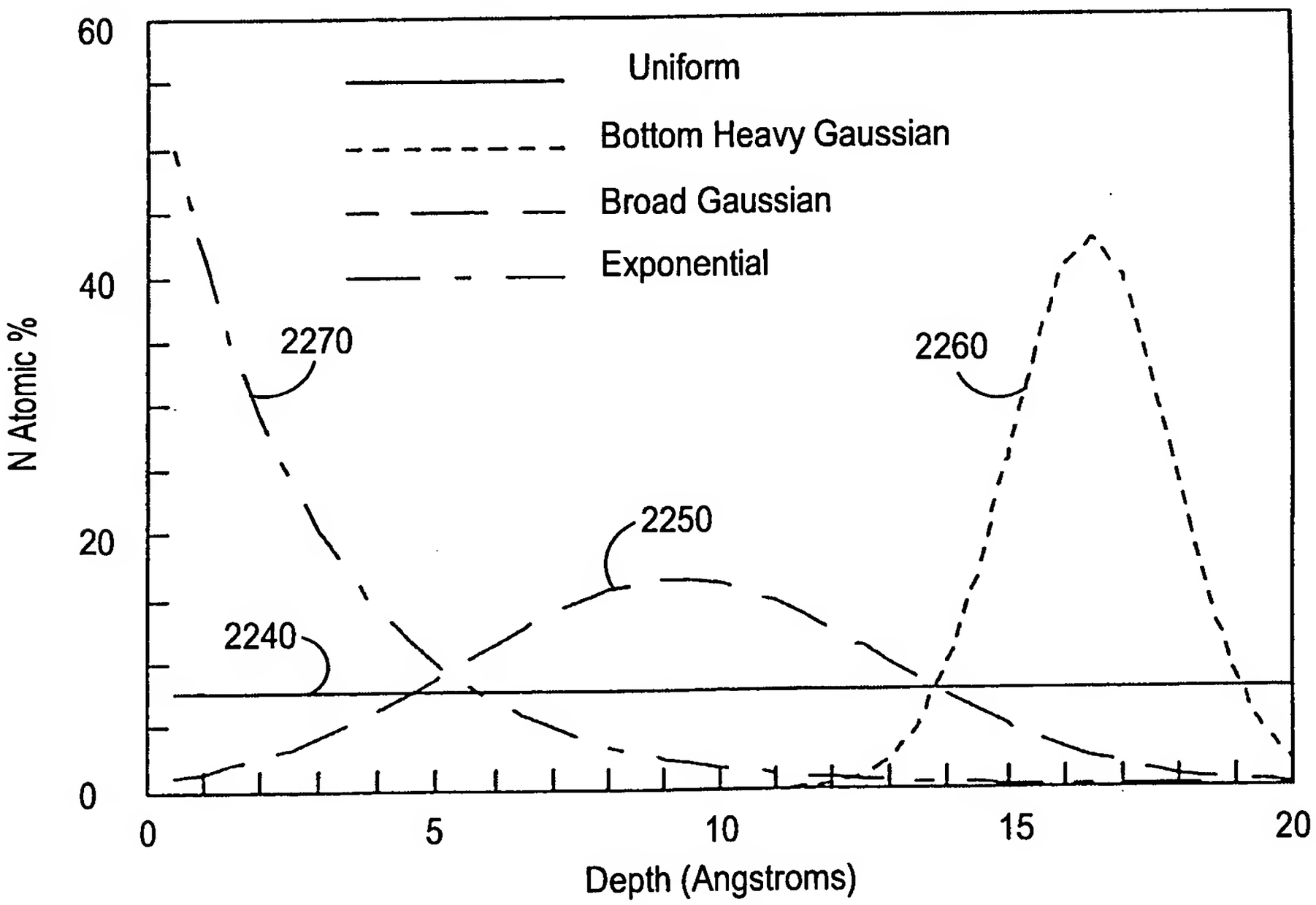


FIG. 22A

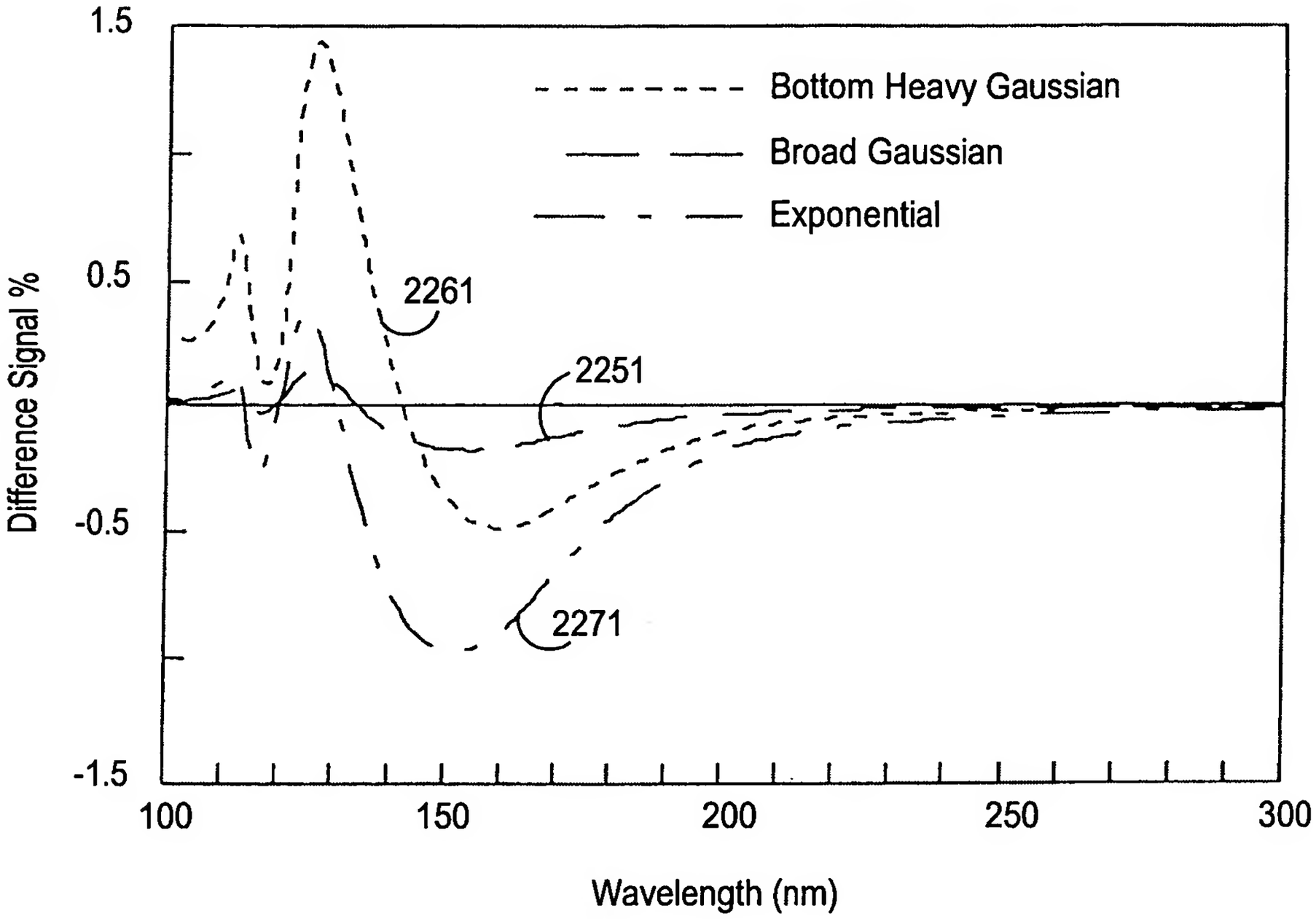


FIG. 22B

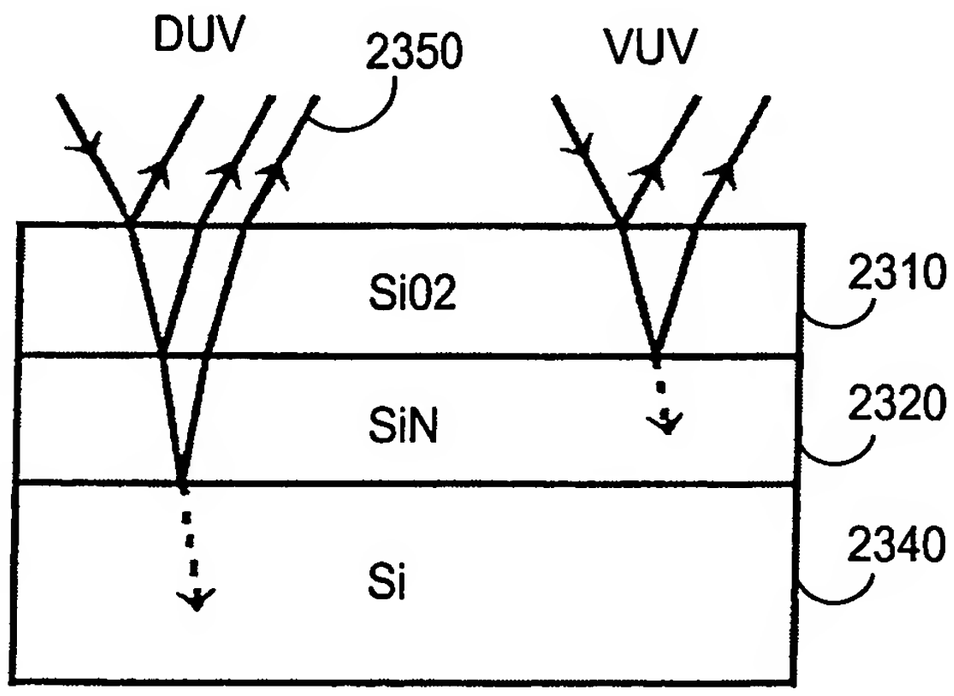


FIG. 23

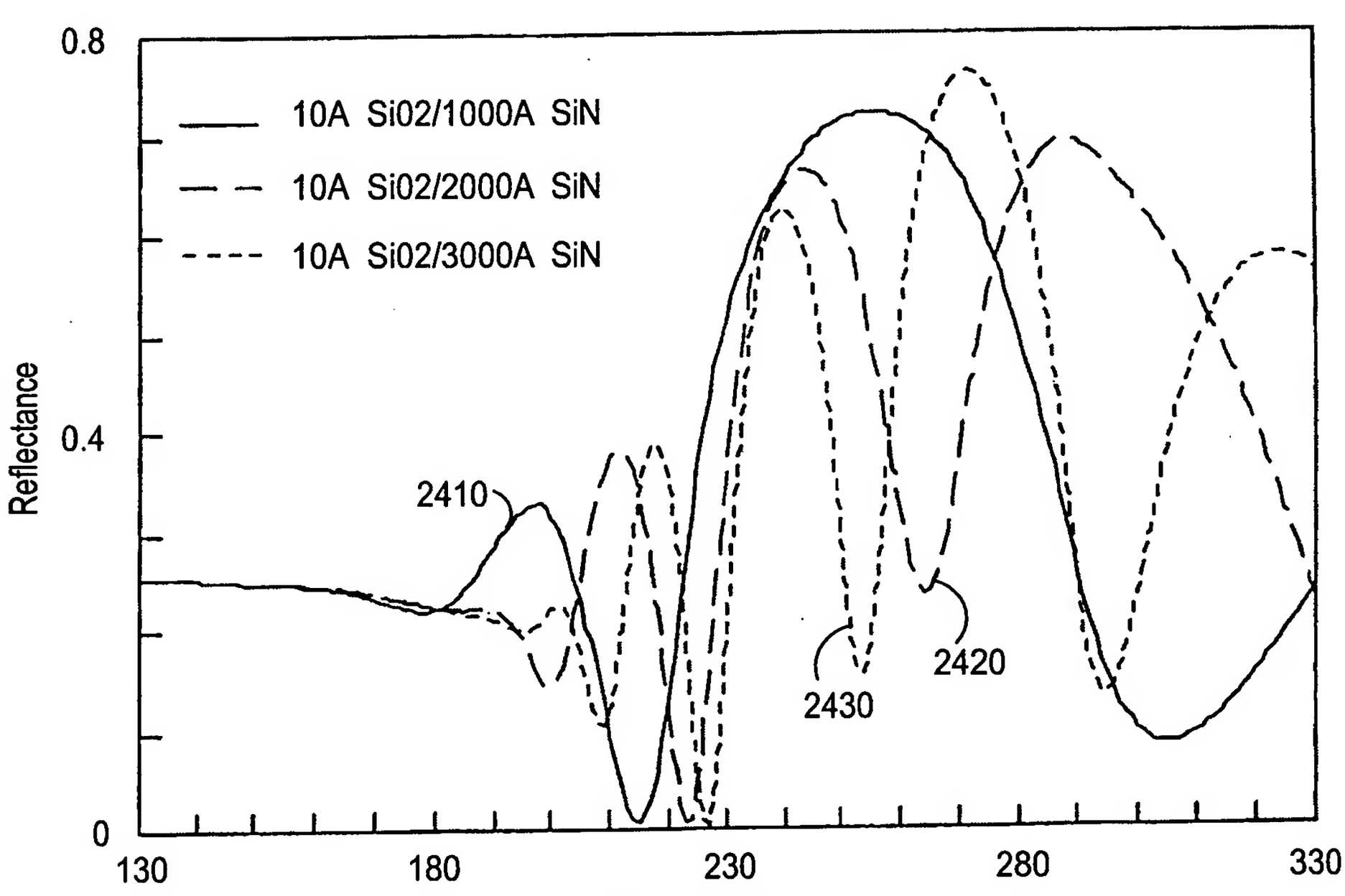

0.8
0.4
0
Reflectance
10A Si02/1000A SiN
10A Si02/2000A SiN
10A Si02/3000A SiN
2410
2420
2430
130
180
230
280
330
Wavelength (nm)

Fig. 24

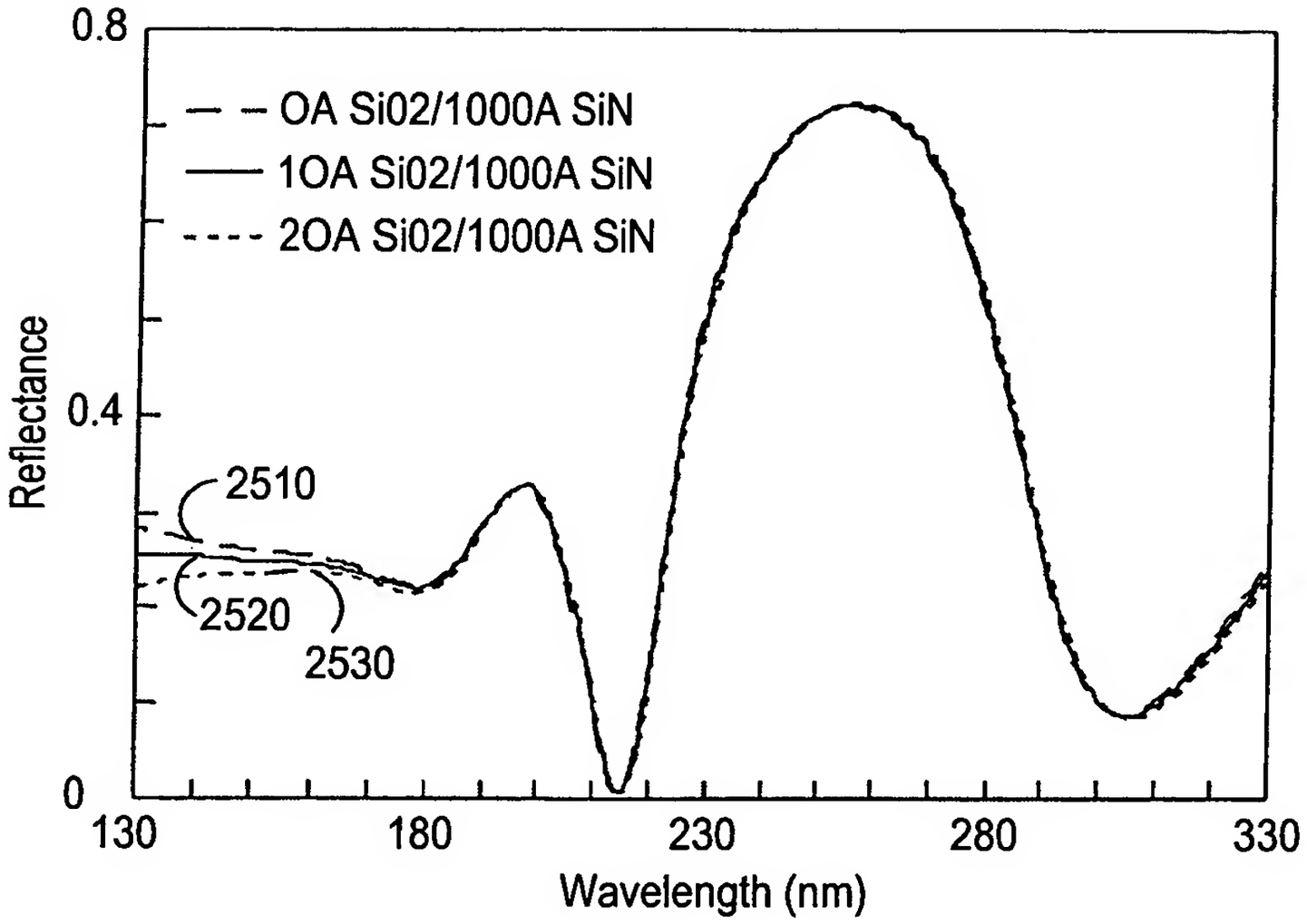

0.8
0.4
0
Reflectance
OA Si02/1000A SiN
1OA Si02/1000A SiN
2OA Si02/1000A SiN
2510
2520
2530
130
180
230
280
330
Wavelength (nm)

FIG. 25

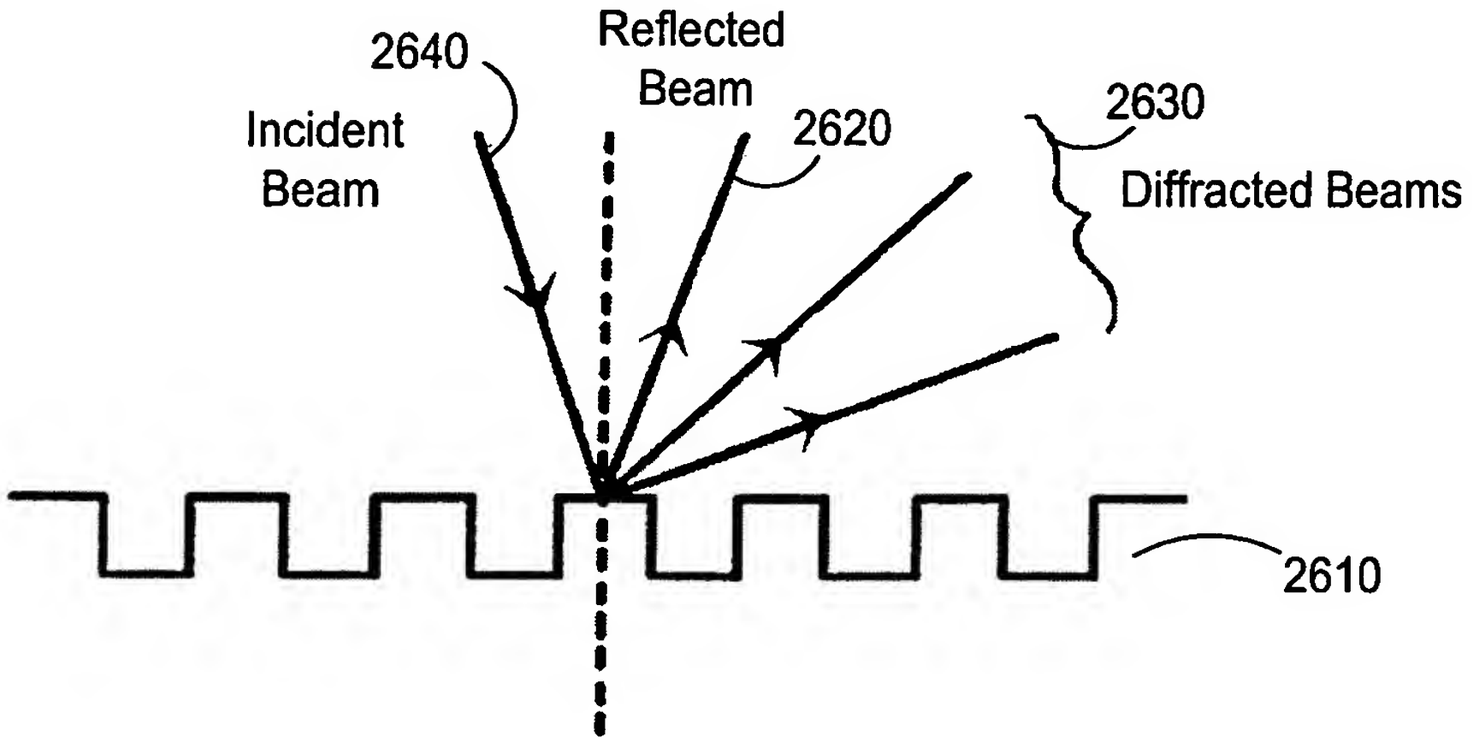

2640
Incident Beam
Reflected Beam
2620
2630
Diffracted Beams
2610

FIG. 26

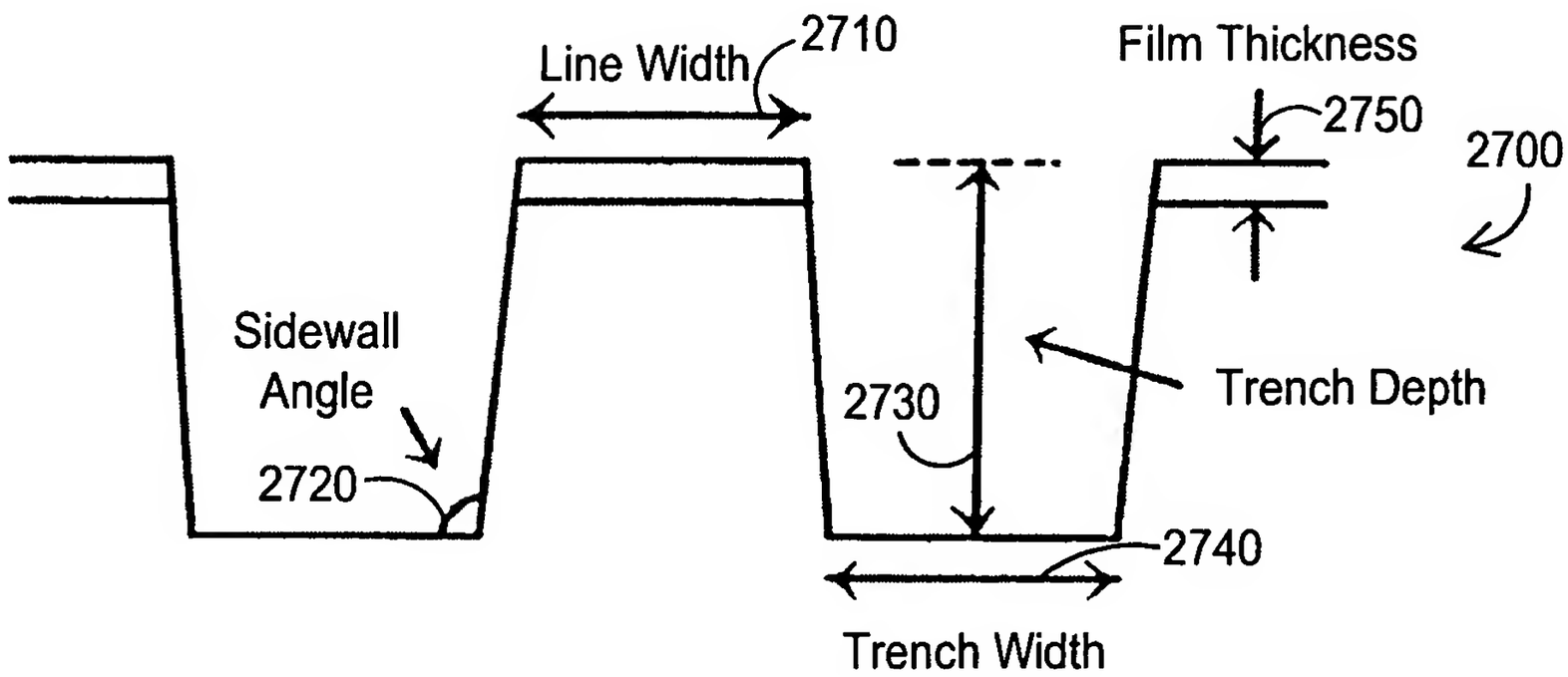

Line Width
2710
Film Thickness
2750
2700
Sidewall
Angle
2720
2730
Trench Depth
2740
Trench Width

FIG. 27

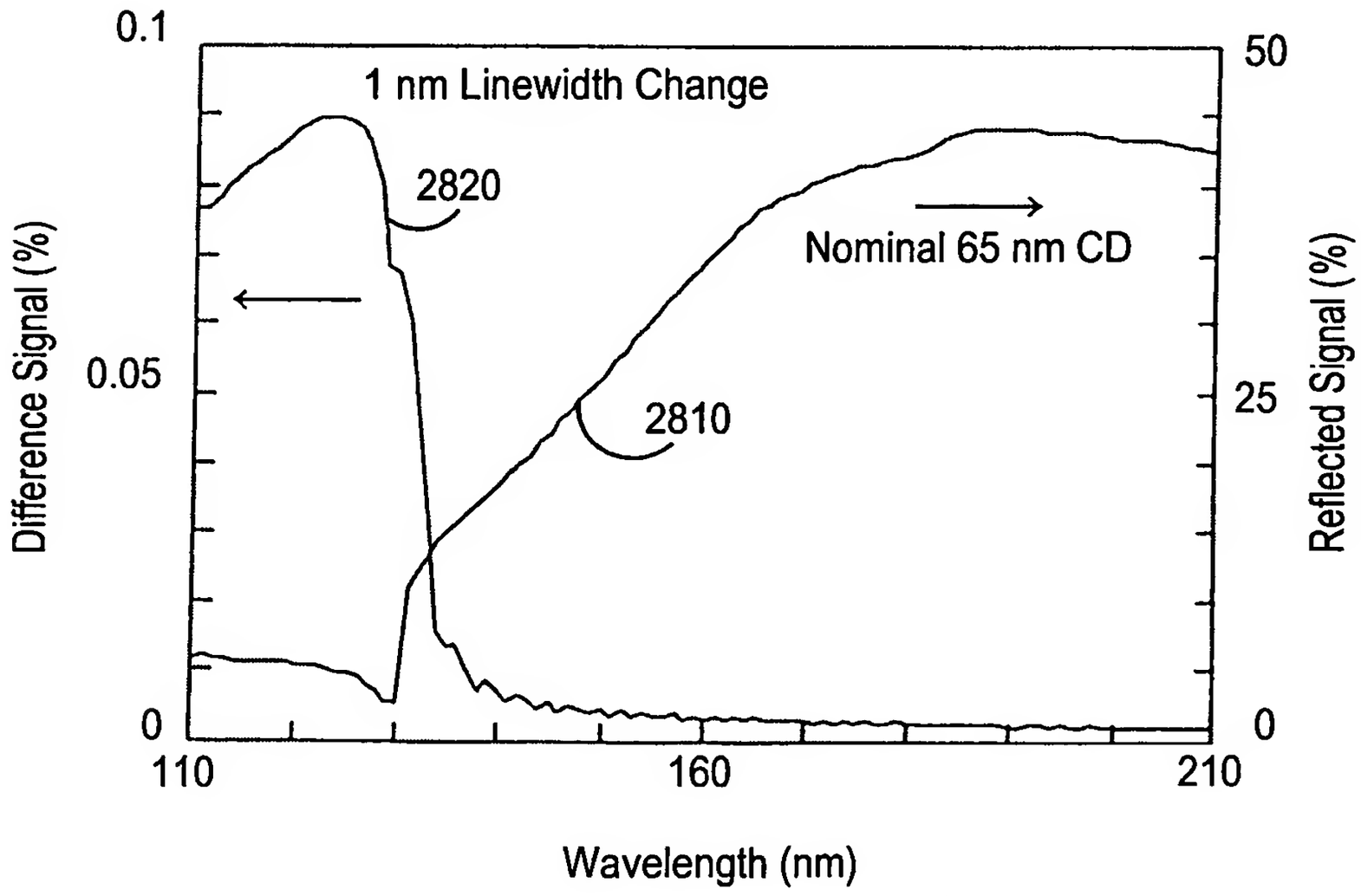

0.1
0.05
0
1 nm Linewidth Change
2820
2810
Nominal 65 nm CD
50
25
0
110
160
210
Difference Signal (%)
Reflected Signal (%)
Wavelength (nm)

FIG. 28

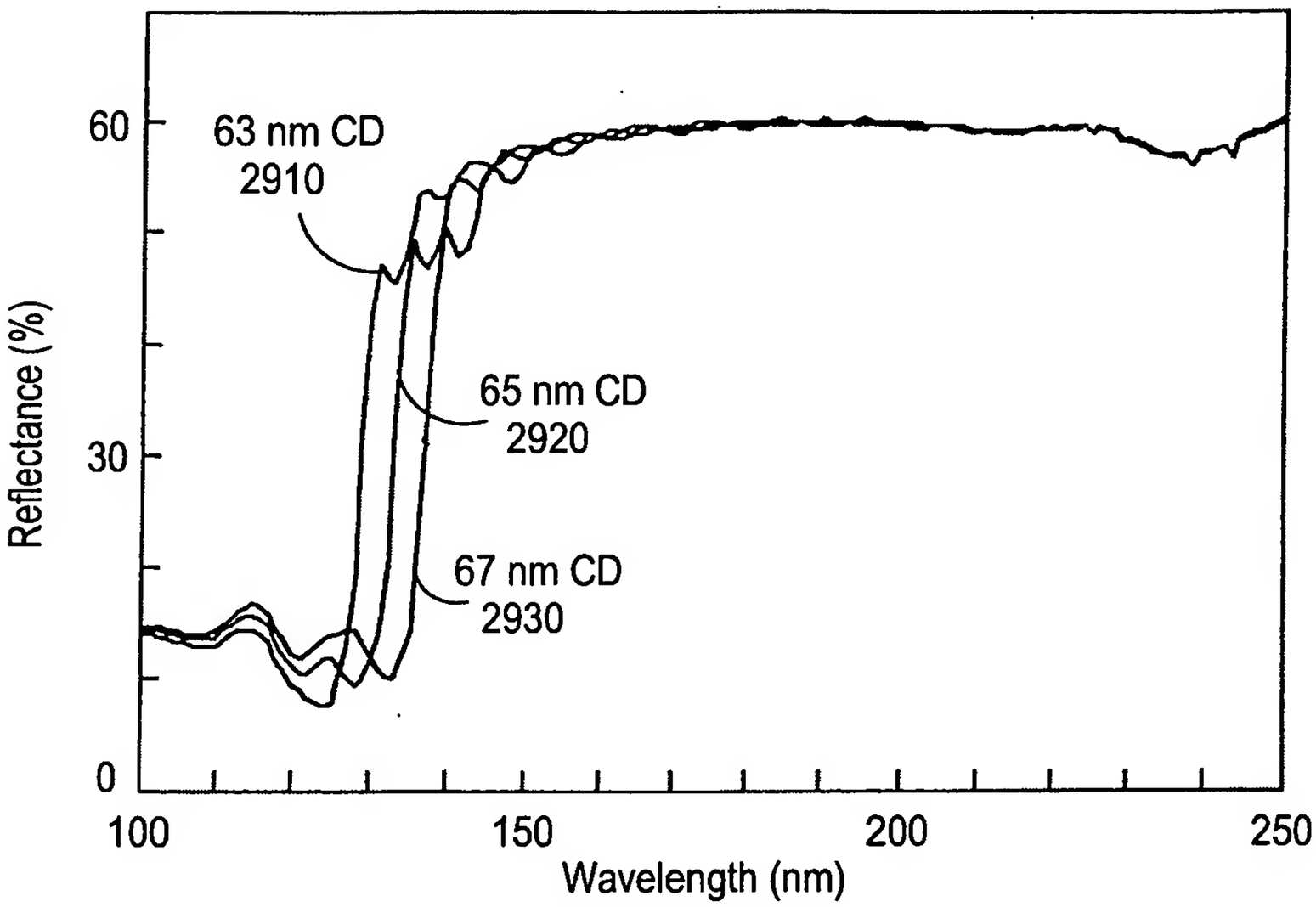

60
30
0
Reflectance (%)
63 nm CD
2910
65 nm CD
2920
67 nm CD
2930
100
150
200
250
Wavelength (nm)

FIG. 29

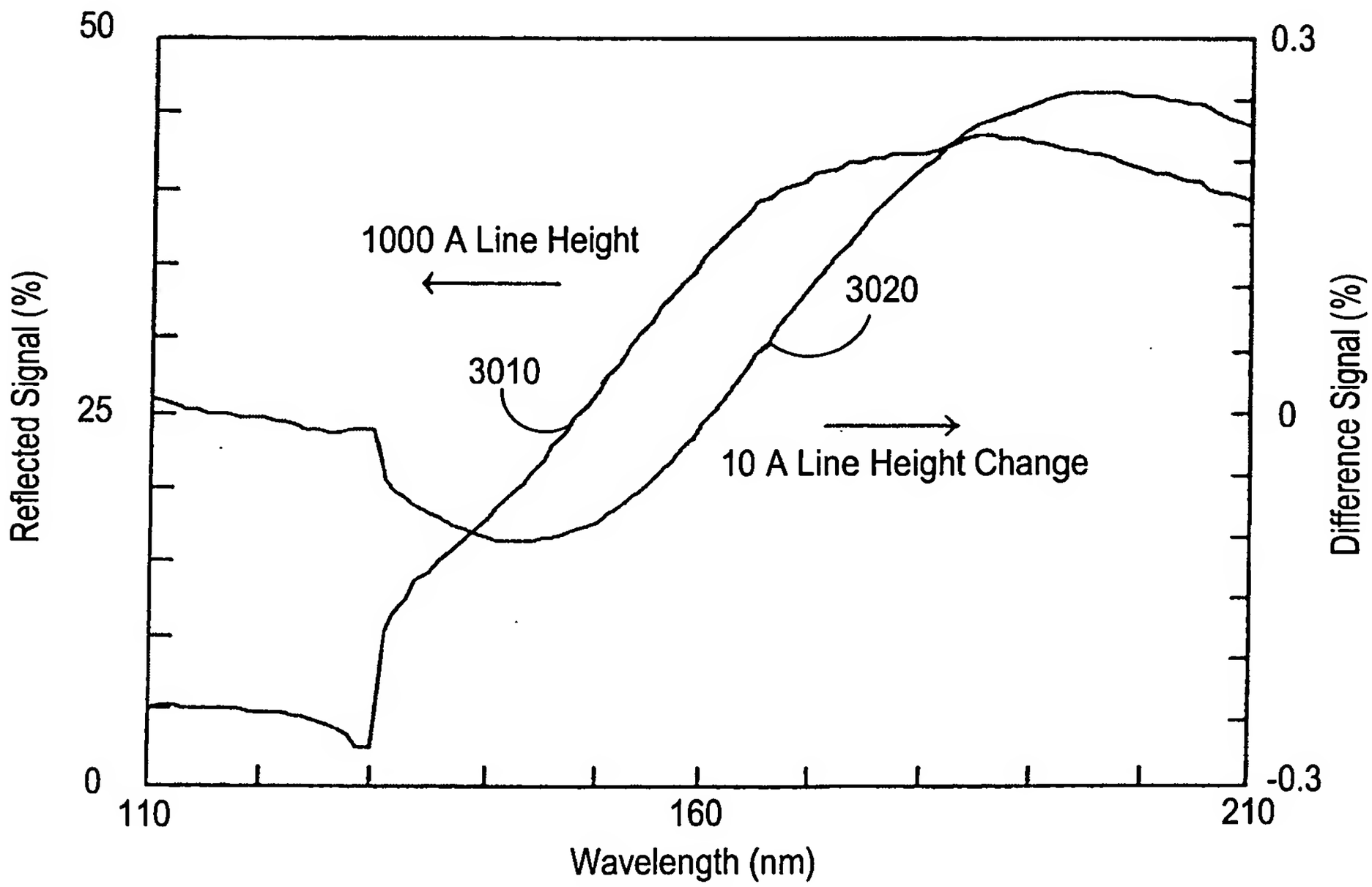

50
25
0
Reflected Signal (%)
0.3
0
-0.3
Difference Signal (%)
1000 A Line Height
3020
3010
10 A Line Height Change
110
160
210
Wavelength (nm)

FIG. 30